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Wayne Tobiasson

J. Lowry, III

TECHNICAL REPORT NO. AFWL-TR-69-122

March 1970

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Air Force Systems Command
Kirtland Air Force Base
New Mexico

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FOREWORD

This research was performed under Program Element 64708F, Project 921A, Task 5.

Inclusive dates of research were December 1968 through March 1969. The report was submitted 16 January 1970 by the Air Force Weapons Laboratory Project Officer, Captain David D. Currin (WLCT).

Information in this report is embargoed under the US Export Control Act of 1949, administered by the Department of Commerce. This report may be released by departments or agencies of the US Government to departments or agencies of foreign governments with which the United States has defense treaty commitments, subject to approval of AFWL (WLCT), Kirtland AFB, NM, 87117.

This technical report has been reviewed and is approved.

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ABSTRACT

An investigation has been made of hangar floor settlement problems at Thule Air Base, Greenland. Inspection of existing instrumentation and soil-cooling systems were accomplished. Results of this inspection are presented. Existing temperature sensors were found to be in excellent condition; however, readout capability was poor. Pumping of ground water has removed no fines from the fill which might have caused settlement. Major cause of settlement was found to be thawing which has contributed to settlement. Duct blockages in the soil-cooling system has also allowed thawing to occur resulting in settlement. Recommendations are made to control further hangar settlement. Blocked ducts in the soil-cooling system should be cleared on an annual basis. The water table should be lowered by lowering the water level in nearby Lake Eddy. Recommendations were also made to improve instrumentation in order that effective operation and maintenance procedures for hangar foundation could be developed.

(Distribution Limitation Statement No. 2)

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SECTION I

INTRODUCTION

1. GENERAL

In late 1968 a conference was held at Hq USAF on the problem of hangar floor settlement at Thule Air Base, Greenland. Descriptions of the present conditions of the hangar foundations and plots of subsurface temperature measurements made during 1968 were presented. Discrepancies in the data presented made it impossible to determine the cause of floor settlement. The US Army Cold Regions Research and Engineering Laboratory (CRREL), Hanover, New Hampshire, was engaged by the Air Force Weapons Laboratory, Kirtland Air Force Base, New Mexico, to conduct an investigation of the problem and to make recommendations for eliminating further hangar floor settlement at Thule Air Base.

Thule Air Base is located on the west coast of Greenland at latitude 76° 32'N and longitude 68° 45'W. The base is situated in a gently sloping east-west valley with a sandy-silt surface containing pebbles and cobbles. The valley is devoid of vegetation except in isolated hollows where moisture and fine-grained soil support grasses and other arctic flora. Polygons, boils, and other signs of frost action are present. It has been estimated that the upper 25 feet of soil contains about 50 percent ice by volume (Ref. 1). The ice exists both dispersed throughout the soil and as isolated lenses and wedges. Upper layers of the underlying sedimentary bedrock are highly fractured and also contain much ice. During the summer, thaw reaches a depth of 1 to 6 feet depending on the nature of the soil, its moisture content, and the type of surface cover. Below the active layer, the ground is permanently frozen to a depth exceeding 1000 feet. The few feet of soil thawed during the summer is refrozen the following winter.

The facilities of Thule were designed to prevent disturbance of the underlying p rmafrost. Roads and airfield pavements were built on insulating blankets of coarse quarry rock and/or non-frost-susceptible (NFS) sand and gravel. Most buildings were elevated above NFS pads on posts to permit circulation of air and prevent building heat from entering the foundation.

The 10 hangars (figure 1) and several other buildings that were designed to withstand heavy floor loads could not be elevated. Instead, a NFS insulating pad was placed on the natural soil, corrugated metal cooling ducts embedded horizontally within the pad, and a composite floor constructed. The floor consisted of a leveling course of concrete, several inches of cellular glass insulation, and, on top, a thick reinforced-concrete slab. The structural frame of the hangars was supported on timber piles founded on permafrost about 32 feet below the hangar floor. The piles were not driven but were placed in 10 to 15 feet deep trenches blasted in the native soil prior to placing the NFS pad. Once the piles were in place, the trench was backfilled with NFS material and the pad constructed above.

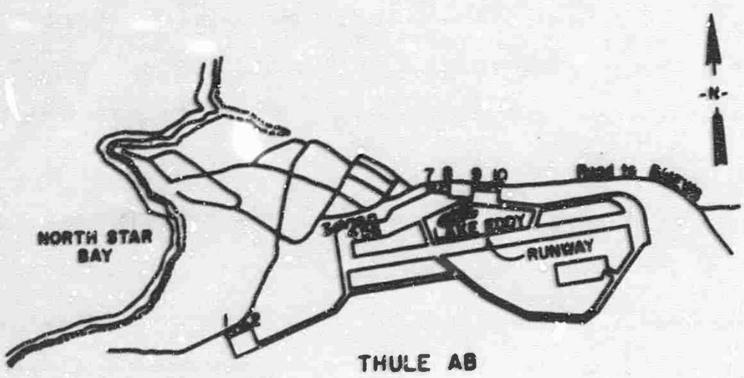


Figure 1. Location of the ~~10~~ Hangars at Thule Air Base

Vertical risers were extended from the corrugated metal cooling ducts to horizontal manifolds at the east and west ends of each hangar. Vertical stacks vented the manifolds to the exterior. To create a chimney effect, shorter stacks were used on the upwind end of each building than on the downwind end. Dampers were provided to block the passage of warm summer air. Prevailing winter sinds are from the east off the ice cap. The object of directing cold air below the hangar floor was to annually freeze back the thawed soil under the hangar so that progressive thaw penetration through the NFS pad and into the high-ice-content permafrost below would not occur. The components of the soil cooling system for hangars 1, 2, 7, 8, 9, and 10 are shown in figure 2. The cooling system for hangars 3, 4, 5, and 6 differs in detail but is the same in principle.

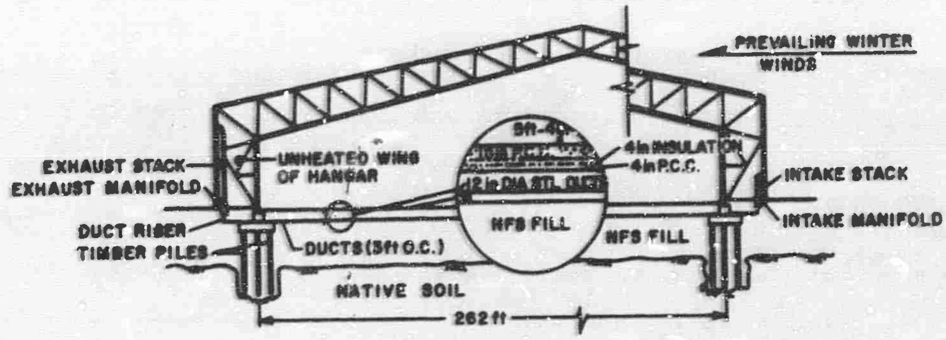


Figure 2. Hangar Soil-Cooling System

2. CHRONOLOGY OF EVENTS AFFECTING HANGAR PERFORMANCE

Hangars 1 and 2 were constructed in 1951. The other eight were completed in 1953. During 1953, extensive drilling and soil sampling were conducted in hangar 10, and over 428 temperature sensors were installed in test pits and boreholes to a maximum depth of 40 feet below the hangar floor. To our knowledge no other operational structure has ever been as thoroughly instrumented for subsurface temperatures as was hangar 10.

As early as January 1954 temperature differences as great as 22°C (40°F) were present between the inlet and outlet ends of the open ducts. The upwind end of the ducts was colder and the soil froze, however, near the downwind end the soil did not completely freeze back. There was no indication of floor settlement at that time. Wind velocity measurements in the risers of open ducts verified that air was flowing through the cooling system.

During 1955, a theoretical study (Ref. 2) of the hangar 10 soil-cooling system was conducted by the Arctic Construction and Frost Effects Laboratory (now a part of Cold Regions Research and Engineering Laboratory). Analysis of data collected to that date indicated that the air cooling capacity of the ducts was used up in the upwind three-fourths of the ducts and no cooling was experienced at the downwind end. Model tests were suggested to evaluate the effect of changes to intake and exhaust ports and manifolds.

By 1956 it was clear that the pad was not refreezing annually. The following winter, blocked ducts were steam-cleaned but in the spring of 1957 they were again blocked. Because of the blocked ducts and distress to a section of the runway, an investigation (Ref. 3) was conducted that summer to

a. Ascertain the influence of ground water

b. Determine the nature of duct blockage

c. Clear all blocked ducts to ensure that the soil freezes during the following winter

Subsurface water flows were detected by introducing a fluorescent dye into observation wells drilled in paved areas adjoining the hangars. Two water wells and two observation wells were also drilled in hangars 1, 2, 7, 8, 9, and 10. At that time thermocouples were also installed in hangars 1 through 9. The dye study indicated that the quantity of subsurface flow throug the fill far exceeded the anticipated amount. The Metcalf and Eddy report states that the main flow of water in the vicinity of hangars 9 and 10 came from Lake Eddy. (The authors feel that observation well measurements and water table cross sections in that report appear to contradict this conclusion and we feel that the major flow was actually from the east along the taxiway rather than from the south. The most significant fact, however, is that vast quantities of subsurface water were detected.)

Drainage from South Mountain was clearly established as the source of ground water flowing in the vicinity of hangars 1 and 2.

A test pit was dug in each unheated end of hangar 10. They revealed that the ducts were sealed with layered ice and that steaming during the winter of 1956-1957 had only cleared one quarter of the duct cross section at the east end of the hangar. The level of the ice on the west end was 6 inches lower than that on the east end and may also indicate a westerly subsurface flow. However, 20 feet high piles of snow had been left to melt on both side of the hangar and variations in the melt rate of these piles may have been responsible for the difference in ice thickness. During summer rains, roof drainage and pavement runoff were observed entering the duct risers 2 feet below the outside ground surface. It was also noted that melt from ice masses produced by steam leaks in the duct-cleaning header pipe in the unheated wings of the hangars was flowing into the NFS material.

Of the five sources of water potentially responsible for duct icing (i.e., regional ground-water flow, pavement and roof runoff, melt from adjacent piles of snow, infiltrating snow, and steam-line leaks) infiltrating snow was thought to be the least significant. However, it was noted that during high winds, blowing snow entered both intake and exhaust stacks.

The year 1957 is still remembered as "the year of the big thaw" at Thule, and that fall de-icing the duct in hangers 7 through 10 was an extensive job which cost the Air Force about $50,000.

Another airfield drainage investigation was conducted during the 1958 thaw season (Ref. 4). Rapid subsurface channelized flow was detected in several areas. The most notable was below the southwest corner of hangar 4 where severe floor settlement had developed. Holes drilled there showed that a narrow channel had thawed to a depth of 18 feet while the surrounding soil was frozen to within 5 feet of the surface. Localized rapid subsurface flow quite likely washed away some of the finer particles in the upper 5 feet of NFS gravel and deposited them in the 5-foot thick pad of coarse quarry rock below. This may have created voids in the upper half of the NFS pad and subsequent floor settlement. However, since the NFS pad below hangar 4 is estimated to be about 10 feet thick and the thaw locally reached a depth of 18 feet, it is also quite likely that a significant depth of permafrost was melted. Since that material probably contained about 50 percent ice by volume, large localized settlements could result. It is suggested that the floor distress was a combination of soil erosion and permafrost melt, with melt being the more significant of the two factors.

During 1958, it was also observed that the depth of thaw was 18 to 24 inches less under that portion of the runway previously painted white than under unpainted portions. Although no conclusive evidence exists, the reduction in depth of thaw suggests that pavement painting altered the courses of ground water by converting the deep channels that gathered ground water to dikes which blocked and diverted flow.

During 1959, Lake Eddy was lowered to elevation 186, the entire runway was painted white, and water was pumped from the northwest water well in hangars 1, 2, 7, 8, 9, and 10 to prevent flow into the soil-cooling ducts.

Another airfield drainage investigation conducted in 1960 (Ref. 5) showed that water from Lake Eddy was not flowing toward hangars 7, 8, 9, and 10. Westward flow from the lake, while less than in the past, was continuing. Pavement painting had been most effective in reducing thaw penetration. A maximum thaw depth of 8 feet was measured under unpainted pavements while 5-1/2 feet was the maximum under painted areas.

In the spring of 1960 a 20-foot long area near the southwest corner of hangar 1 was undermined by melting snow piled in the area. At the same time, Lake Eddy was lowered an additional 4 feet to elevation 182. Twenty-three million gallons of water were removed before July, and it is interesting to note that the elevation of the lake remained constant from that time to freeze-up without further pumping.

A vigorous dewatering program was conducted in hangars 1, 2, 7, 8, 9, and 10. Pumping from the northwest water well in each hangar began in July and continued periodically until mid-September. It is stated that the 1960 thaw season was warmer than the 1959 season and three times as much pumping was necessary in 1960. (The authors suggest the pumping of three times as much water may have caused three times as much flow.)

Cleaning of ducts in hangars 1 through 10 commenced late in June and was completed in mid-September. In reference 5 Metcalf and Eddy mention for the first time that duct blockages were occurring in hangars 3, 4, 5, and 6. Although much time and effort were devoted to duct cleaning in all 10 hangars, many ducts could not be cleared. That report recommends that (1) snow should be removed from the airdrome--not piled adjacent to the hangars, (2) the areas adjacent to hangars 7 through 10 should be paved, (3) the ducts in hangars 1 and 2 should be rehabilitated, and (4) the ground water level should be maintained 18 inches below the soil-cooling ducts by pumping.

The hangars have also been inspected by personnel of the US Army Corps of Engineers. Mr. E. F. Lobacz of the Cold Regions Research and Engineering Laboratory participated in a comprehensive inspection of Thule Air Base and outlying facilities during April 1960. Recommendations resulting from that inspection emphasize the distress caused by steam line leaks in the unheated ends of the hangars, the importance of periodically checking and removing ice from the soil-cooling ducts, and the problem of foundation saturation by melting of adjacently piled snow.

From 1960 to the present time there is little formal data available since airfield drainage studies were not conducted. However, it appears that the ducts in hangars 1 and 2 were never rehabilitated and that removal of snow from the airdrome was initiated only recently.

Sometime in 1962 or 1963 settlements were noticed near the northwest water well in hangar 10. In 1964 a 5-x-5-foot test pit was excavated 12 feet below the center of the depression dish in that hangar (Ref. 6). The floor at the test pit was depressed 1.1 feet below the unaffected hangar floor. While digging the pit it was noticed that a 1-1/4-inch separation existed between the cellular glass insulation and the 4-inch concrete slab below. Evidently the lower slab and the NFS pad deflected as the natural soil below was melted. The upper 15-inch reinforced concrete slab was stiffer and deflected only a portion of the total mount, leaving the 1-1/4-inch void below.

The NFS fill was found to be quite tight, and a comparison of graduation curves with those obtained in 1953 indicated that the amount of fine material in the soil had not changed appreciably. The ducts uncovered were clear and cold air was blowing through them. It was concluded that floor settlement was the result of problems in the native soil rather than in the NFS pad.

In 1964 several Air Force personnel participated in a thermocouple workshop-seminar at the Cold Regions Research and Engineering Laboratory directed toward more effective monitoring and analysis of subsurface temperatures by the Air Force. The participants were provided with the handout "Analysis and Evaluation of Thermocouple Observations--Thule Air Base and Sondrestrom Air Base." The handout "Location and Thermocouple Spacing of Ground Temperature Installations, Thule Air Base, Greenland" was included as an appendix.

During 1968 Captain Leonardo Miranda of the Civil Engineering Division at Thule Air Base conducted a study of the Thule hangars. Lacking information from 1960 to the present time, he sent a questionnaire to the Civil Engineering Department of the Danish Construction Corporation (DCC), the firm that has maintained Thule Air Base during the past several years. The following pertinent information was provided by DCC:

a. Duct cleaning has been attempted every summer since 1964 in hangars 1, 2, 7, 8, 9, and 10.

b. Twelve ducts in hangar 10 have been blocked since 1963 and 26 ducts in hangar 2 have been blocked since 1965.

c. Dewatering from water wells in the hangars has been accomplished between August and February every year since 1963. All pumping in hangars 1, 7, 8, 9, and 10 has been from the northwest water well. In hangar 2, the southeast water well was used.

d. Leaks in condensate return units have developed in hangars 7, 8, and 9.

e. The settlement in hangar 2 started in 1965; in hangar 7 in 1966; in hangar 8 in 1967; in hangar 9 in 1966; and in hangar 10 sometime before the summer of 1963. (On 9 August 1964 a settlement of 1 foot was measured in hangar 2 by Mr. E. F. Lobacz of the Cold Regions Research and Engineering Laboratory.)

Surveys conducted during the fall of 1968 by personnel of the Civil Engineering Division indicate that floor settlement has created dishes whose centers are depressed the following distances below unaffected portions of the hangar floor:

Hangar	Depth (in)
1	2.5
2	42
3	1.5
4	8
5	Not measured
6	11
7	12
8	10
9	12
10	27

SECTION II

ON SITE INSPECTION

1. GENERAL

An on-site inspection was conducted by the authors during the period 3 to 13 January 1969. The objectives were to

a. Test and determine the suitability of the temperature readout hardware presently being used by the Civil Engineering Division at Thule Air Base

b. Inspect, test, and repair the subsurface temperature sensors in hangars 1 through 10

c. Instruct Air Force personnel in the proper method of measuring temperatures

d. Ascertain the condition of the soil-cooling system in each hangar

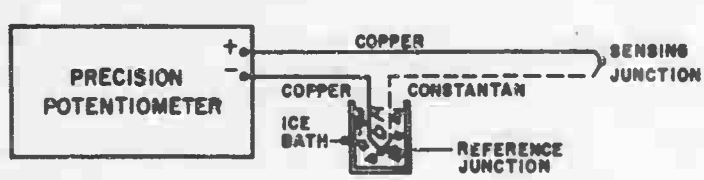
2. DEFINITION OF A THERMOCOUPLE

Temperatures in and below the floors of the Thule Air Base hangars are measured by the use of thermocouples. In essence, a thermocouple is a very weak battery created simply by joining wires of two dissimilar metals. The strength of this battery changes with changing temperature and by measuring the small voltage produced, the temperature at the bi-metallic junction can be determined. When an electrical circuit consisting of two dissimilar wires is closed, two thermocouples are created. They are in electrically opposite directions and if the two junctions are at the same temperature, the voltage produced by one offsets that produced by the other. If the two junctions are not at the same temperature, a net voltage is produced. Consequently, it is not the temperature at a single thermoelectric junction that is measured but rather the difference in temperature between two junctions. The Thule Air Base thermocouples are wired so that one of the junctions (the sensor) is placed at the point where an unknown temperature is to be measured and the other (the reference) is placed in a mixture of ice and water which maintains itself at 0°C (32°F). The two dissimilar wires used at Thule Air Base are copper and constantan. Tables are available for converting voltage readings obtained on a precision potentiometer to temperature for these wires when the reference junction is maintained at 0°C (32°F).

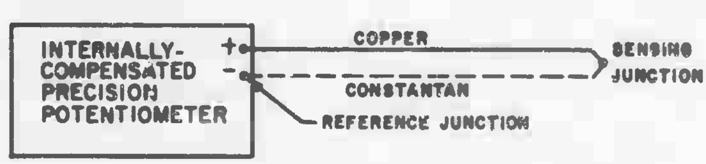
3. SUITABILITY OF READOUT HARDWARE

Precision potentiometers used at Thule Air Base before 1965 were designed for thermocouple circuits with an ice bath reference junction. A circuit diagram is shown in figure 3a. The potentiometer used since late 1965 (Rubicon Model No. 2736) cannot be used with an ice bath. Instead, the wires from the sensing junction must be connected directly to the instrument. The copper wire is connected to the positive terminal and the constantan wire to the negative terminal. To simplify this brief discussion, the wires within the instrument can be considered to be copper. So connected, a reference junction is created where the constantan wire attaches to the negative terminal of the instrument (figure 3b). In the past the use of negative terminal reference junction has been discouraged because it is virtually impossible to maintain a stable reference temperature (say, ±1/4°C, ±1/2°F) under arctic conditions.

The Rubicon Model No. 2736 precision potentiometer was purchased by the Air Force on the manufacturer's recommendation in place of a model suggested by the Cold Regions Research and Engineering Center, which was no longer available. It contains a rather new feature not evaluated in the the field by USA TSC. It is equipped with an internal compensator designed to maintain the measuring circuit in balance no matter what temperature exists at the negative terminal, withing the range 0°C to 49°C (32°F to 120°F).



a. Ice Bath Reference Junction



b. Negative Terminal Reference Junction

Figure 3. Thermocouple Circuit Diagrams

However, tests conducted at Thule Air Base by the authors in January indicate that temperature fluctuations at the negative terminal do affect results. The wire-wound compensating resistor is within the potentiometer and the reference thermocouple that it compensates for is located outside the instrument case. Although the two are electrically and thermally connected by a stout wire, a temperature difference can develop between the two locations and errors will result. Direct breathing on the terminals temporarily induced a 1 to 2°C (2 to 4°F) error and when a cigarette was placed near the negative terminal, a 3°C (6°F) error resulted. When readings were taken with the instrument placed in -7°C (+20°F) air and exposed to 20 mph winds, a 2 to 4°C (4 to 7°F) change was noticed. With snow packed on the terminals, a 1.5°C (3°F) error resulted. The above errors were determined by measuring the temperature of a thermocouple located in a mixture of ice and water which was stable at 0°C (32°F).

The possibility of introducing unknown errors is ever present when an internally-compensated potentiometer is operated in a transient temperature environment. Consequently, it is felt that the Rubicon internally-compensated potentiometer is not suited for temperature measurement at Thule Air Base.

4. VALUE OF DATA OBTAINED WITH THE INTERNALLY-COMPENSATED POTENTIOMETER

When using the internally-compensated potentiometer, copper and constantan leads must be connected directly to the instrument. This was accomplished by attaching a copper-constantan jumper cable to the potentiometer and plugging it into the copper-constantan panel boards located in hangars 1 through 9. Consequently, all connections were correct and the readings meaningful with the qualification that some errors exist due to the above-mentioned thermal gradient problem at the negative terminal of the potentiometer.

The thermocouples in hangar 10 are wired into rotary switches, not panel boards. All wires, including a reference junction which must be placed in an ice bath and the copper wires to be attached to the potentiometer, are permanently connected to the switch. Since 1965, the two copper wires have been connected to the potentiometer and no ice bath has been used. Consequently, the reference junction hung in the air and its temperature fluctuated as the observer breathed, heaters turned on, and doors opened. Since unknown temperature differences existed between the internal compensator and the dangling reference junction, errors were introduced and all hangar 10 readings from 1965 to the time of this inspection are of questionable value.

5. CONDITION OF INSTALLED INSTRUMENTATION

All thermocouple assemblies in hangars 1 through 10 were inspected. The location of each assembly is shown in Appendix I. Many of the cover plate support brackets for floor assemblies were broken. New brackets were fabricated and welded in place. Now all covers function as initially intended. Upon removal of several cover plates, the assemblies below were found immersed in liquid. The recess was bailed dry, but it can be expected that in the future liquids will inadvertently enter and additional bailing will be necessary. New assemblies should be watertight.

When possible, switches and panel boards were cleaned and reconnected. Several damaged panel boards and corroded switches were removed. Continuity was established both before and after disconnecting each wire and tags were installed. The present condition of all assemblies is listed in table I. Photographs of typical switch and panel board assemblies are shown in figure 4.

Where switches and panel boards have been removed, measurements must now be taken by holding the bare wires against the copper-constantan plug of the jumper cable. This scheme is slow and tedious and it is suggested that replacement switches and panel boards be secured for these assemblies. Since most panel boards in hangars 1 through 9 are badly corroded, it is suggested that they be replaced under Phase II of this study if pursued.

All thermocouples were read with a Leeds and Northrup No. 8686 precision potentiometer. An ice bath reference junction was used. Although several switches and panel boards were damaged, the sensors themselves were in excellent condition. All 100 thermocouples in hangars 1 through 9 were operable and of the 428 sensors in hangar 10, only five could not be used. Overall, more than 99 percent of the sensors were functioning, though many were over 15 years old. Even those located directly below the 2.2-foot deep settlement depression in hangar 10 were functioning.

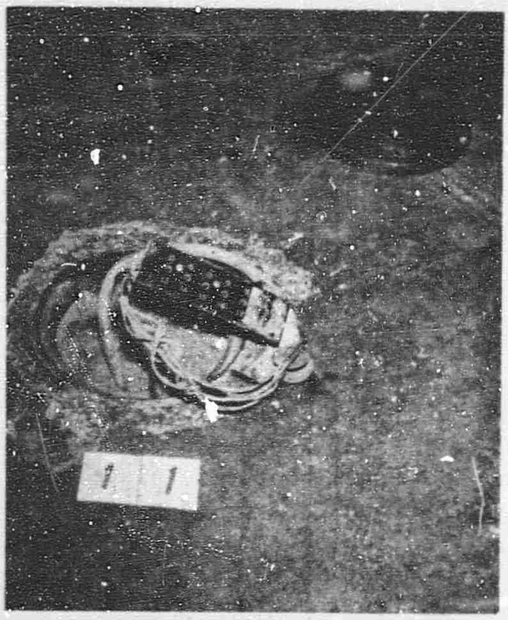
6. INSTRUCTION OF USAF PERSONNEL

Personnel were instructed in the fundamentals of thermoelectric temperature sensing. After this instruction, a series of readings were obtained at panel boards and rotary switches with both the Rubicon Model No. 2736 and the Leeds and Northrup Model No. 8686 potentiometers.

Table I

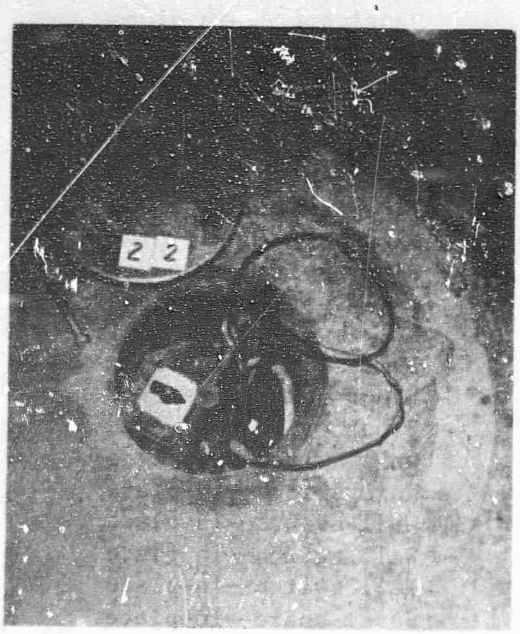
PRESENT CONDITION OF HANGAR THERMOCOUPLE ASSEMBLIES

	Thermocouples		
Assembly	Original number	Presently functioning	Type and condition of switching mechanism
1	5	5	Panel board--removed
2	5	5	Panel board--removed
3	5	5	Panel board--removed
4	5	5	Panel board--removed
5	5	5	Panel board--removed
6	5	5	Panel board--in-place
7	5	5	Panel board--in-place
7A	5	5	Panel board--in-place
8	5	5	Panel board--in-place
9	5	5	Panel board--in-place
10	5	5	Panel board--in-place
11	5	5	Panel board--in-place
12	5	5	Panel board--removed
13	5	5	Panel board--removed
14	5	5	Panel board--removed
15	5	5	Panel board--removed
16	5	5	Panel board--in-place
17	5	5	Panel board--in-place
18	5	5	Panel board--in-place
19	5	5	Panel board--in-place
20	24	24	Wall switch--in-place
21	24	24	Wall switch--in-place
22	24	23	Floor switch--in-place
23	24	24	Floor switch--in-place
23A	12	12	Floor switch--in-place
24	24	24	Floor switch--removed
25	24	23	Floor switch--in-place
26	24	23	Floor switch--removed
27	24	24	Wall switch--in-place
28	24	24	Wall switch--in-place
29	24	24	Wall switch--in-place
30	24	22	Floor switch--removed
31	24	24	Floor switch--removed
32	24	24	Wall switch--in-place
32A	12	12	Wall switch--in-place
33	24	24	Wall switch--in-place
34	24	24	Wall switch--in-place
35	16	16	Wall switch--in-place
36	8	8	Panel board--in-place
37	6	6	Switch--in-place
39	6	6	Switch--in-place
52	8	8	Panel Board--in-place



a. Panel Board in Place

b. Panel Board Removed



c. Rotary Switch in Place

d. Rotary Switch Removed

Figure 4. Present Condition of Typical Thermocouple Assemblies

There are several RCA technicians at the Ballistic Missile Early Warning System (BMEWS) electronic instrument shop who are knowledgeable in thermoelectric temperature sensing. One individual reads subsurface thermocouples at BMEWS at the present time. Since it is understood that RCA is taking over additional functions at Thule Air Base, it may be advisable for the Air Force to transfer the responsibility for measuring thermocouples to them. This should also establish better continuity because the civilians quite frequently work at Thule for several years while Air Force personnel rotate annually.

7. CONDITION OF SOIL-COOLING SYSTEM IN EACH HANGAR

The cooling ducts in each hangar are laid in a generally east to west direction. Those in hangars 1, 2, and 7 through 10 are numbered from 1 to 63 with number 1 at the southern wall near the hangar doors and number 63 at the northern end of the hangar. There are 9 upwind and 9 downwind stacks in the unheated wings of hangars 1, 2, 7, 8, 9, and 10. They are labeled A through I from south to north. In hangars 3 through 6, the manifolds and stacks at each end of the building are combined into a single air intake or exhaust enclosure built outside the basic structure.

All 10 hangars were visually inspected and wind velocity measurements were obtained with a hand-held Alnor velometer in the cooling ducts and in the intake and exhaust stacks. Air velocity was measured in both the upwind and downwind duct risers in hangars 2, 9, and 10 by crawling the length of the manifolds. In the remaining hangars, velocities were measured in several but not all duct risers. All hangars were inspected after several days of high winds and blowing snow during which time gusts to 60 mph developed and for the better part of 1 day a Phase III condition was in effect.

In hangar 1 no snow had infiltrated into the downwind (west) manifold and only a dusting of snow was evident in the upwind manifold. A few ducts near the north and south ends of the hangar were blocked with ice. Other ducts appeared clear but velocity measurements were less than 1 mph (88 fpm) as compared to 2 to 4 mph in other hangars under about the same outside wind conditions (i.e., easterly winds 3 to 10 mph). The low flows are probably because of constriction of the air by ice build-up within the ducts. Measurements in the downwind exhaust stacks indicated an upward velocity of 3 to 4 mph, which is similar to that measured in other hangars.

In hangar 2 there was again no sign of snow infiltration downwind and only a dusting of snow within the upwind manifold. Only three of the 63 ducts were clear; the duct risers of all others were found blocked with ice. Air velocity measurements in the downwind stacks indicated an upward flow of about 3 mph even in partitioned-off sections of the manifold containing only blocked ducts. It was evident that air from the unheated end of the hangar was being drawn through the numerous cracks and gaps in the wooden walls and roof of the manifold, then up the stack to the outside. The flow in exhaust stack F was 5 to 8 mph. Stack F is directly above the only open ducts (Nos. 40, 43, and 44) and the increase in velocity is attributed to pressure on the upwind end of the soil-cooling system which forces air through the ducts.

Only the upwind end of the soil cooling system in hangar 3 could be examined. The downwind ventilation structure is between inner and outer building walls and personnel access is not possible. The upwind stacks and manifold are completely outside the hangar wall. Entrance is facilitated by doors at the north and south ends of the upwind manifold. Cooling ducts were installed about 5 feet below the southern two-thirds of the hangar floor, but pans directly below the concrete floor slab are used to cool the northerly third. All pans were clear under the hangar as far as one could see with a flashlight (about 50 feet). Air velocities in the pans were 1 to 2 mph. Although the latter could result from blockages near the downwind end, it was felt that, in part, these low velocities were caused by the shape of the inlet stacks. As shown in figure 5 the stacks do not open into the wind but are, in effect, upsidedown chimneys that tend to draw air out of, rather than force air into the upwind manifold. Suction on the downwind end of the building probably offsets the upwind chimney effect producing a net downwind flow through the ducts.

The soil-cooling systems for hangars 4, 5, and 6 employ ventilation stacks and manifolds outside the exterior wall on both the upwind and downwind ends of each structure. The air inlet in hangar 4 is more direct than that in hangar 3, and consequently, more snow enters the manifold. The floor of the manifold was covered with snow and the ducts were also partially blocked. Air velocity in the duct risers was 2 mph downward. Observations at the exhaust end of the hangar revealed a possible reason for the low flows. About 3 feet above the concrete floor of the exhaust structure, there is a false floor that contains 11 wooden doors. The doors can be lifted during the winter to permit air flow

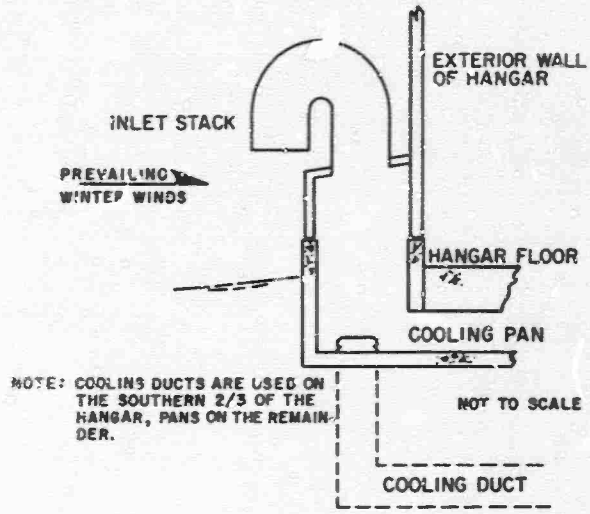


Figure 5. Inlet End of Soil-Cooling System, Hangar 3

through the ducts (figure 6). In hangar 4 all of these doors were open. The fixed portion of the false floor was covered with up to 6 inches of snow.

Figure 6. Exhaust Structure Showing False Floor, Hangar 4

Further inspection revealed that horizontal timbers high in the exhaust structure were also covered with snow. From these observations it was concluded that air is both exiting and entering the vents high on the wall. Air warmed by passing through the soil-cooling ducts rises in the exhaust stack and exits through the vents while cold outside air and snow enters. A possible flow pattern is shown in figure 7.

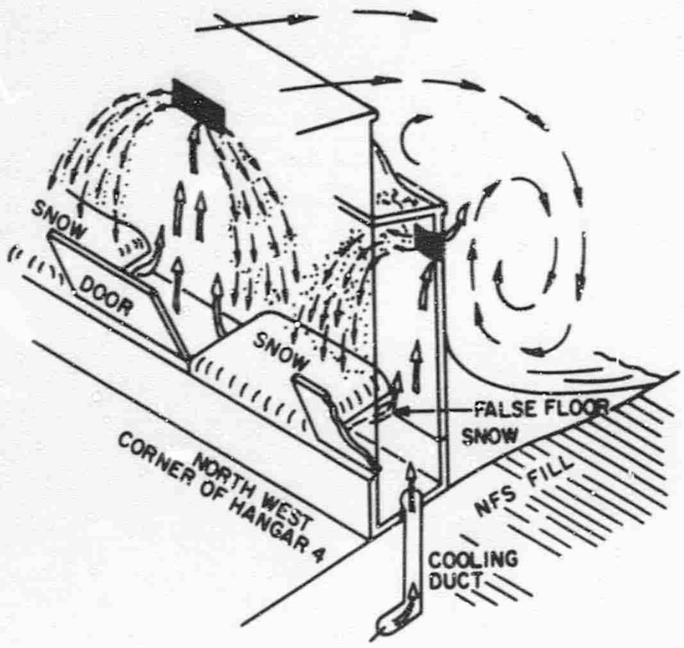


Figure 7. Two-Directional Flow in the Exhaust Structure, Hangar 4

It is evident that little chimney effect is being derived at the downwind end of hangar 4.

No snow was present in the upwind end of the hangar 5 soil-cooling system. Air velocity in the duct risers was measured at about 4 mph downward. Only 7 seven of the 11 doors in the false floor at the downwind end of the hangar were open. A 2- to 4-inch blanket of snow covered the fixed portion of the false floor and the four closed doors as shown in figure 8. The snow indicates that air both exits and enters the hangar 5 exhaust chamber as was described for hangar 4. Less snow was present in the downwind end of hangar 5 and duct velocities (4 to 401/2 mph) were higher than in hangar 4. This indicates that the soil-cooling system in hangar 5 draws air somewhat more effectively than the hangar 4 system.

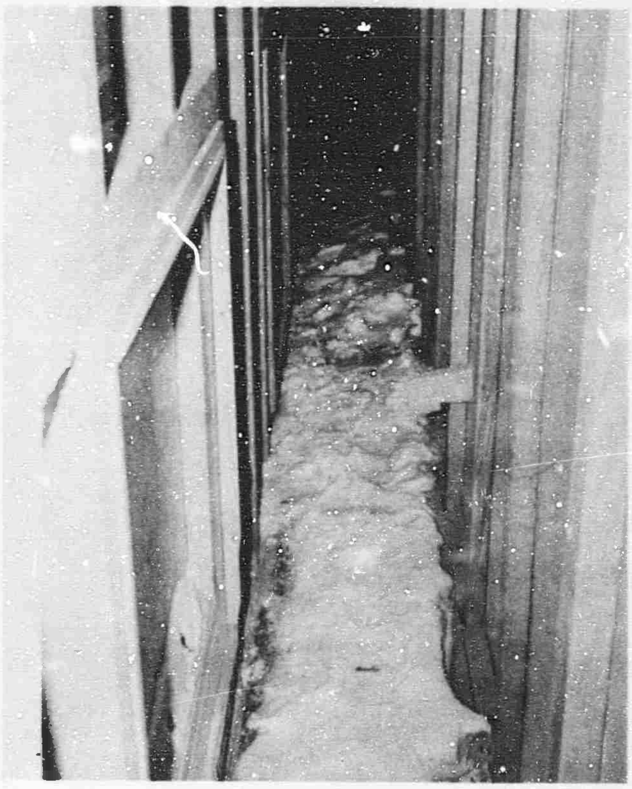


Figure 8. Snow Covering Closed Doors of False Floor in Exhaust Structure, Hangar 5

Neither the upwind nor downwind manifold of the hangar 6 soil-cooling system contained drift snow. All 11 doors in the downwind manifold were open and upward air velocities of 3 to 5 mph were measured in the duct risers.

Since winter prevailing winds are from the east and hangar 6 is upwind of hangars 5 and 4, it is quite possible that the variation in performance of the three identically-constructed soil-cooling systems is directly related to the relative positions of the three hangars.

In hangars 7 and 8 most ducts appeared clear, but some were visibly blocked and others operating at velocities less than 1 mph. Only a dusting of snow had infiltrated the upwind manifold. When an upwind manifold cover was removed, cold air would blow out of the manifold at velocities up to 6 mph. This observation indicates that pressure in the upwind manifold forces air through the ducts. To take advantage of this valuable source of energy, the intake stacks and manifold must be relatively air-tight. The sheet metal stacks are quite tight, but the timber manifolds are veritable sieves. Large gaps and cracks are present in the board walls and roof and many of the duct inspection doors in the roof were lying on the adjacent concrete floor at the time of this inspection.

To verify the leaky nature of the downwind manifold, exhaust stack dampers were temporarily closed and duct velocity measurements obtained. Closing the dampers did not affect the flow of air through the ducts. This test not only illustrated the ease by which air could flow out of openings in the downwind manifold, but also showed the lack of a significant chimney effect on the downwind end of hangars 7 and 8. This was even more graphically illustrated by opening downwind manifold covers. In this situation air flowed <u>down</u> the exhaust stacks and into the unheated end of the hangar.

The downwind end of hangar 9 is free of drift snow and only small amounts of snow are present on the floor of the upwind manifold. Air velocities were measured at all downwind duct risers. Ducts 3, 4, and 57 through 63 were blocked with ice. Ducts 36, 37, 42, 43, 44, 49, 51, 52, and 53 registered flows of 1/2 mph or less. A flow of about 1 mph was obtained for ducts 29 through 33, 38, 39, 40, and 48. The air velocity in the remaining ducts was between 2 and 3 mph. Exhaust stacks A through G registered upward flows between 2 and 4 mph. The damper for stack G is missing. The flow in exhaust stack H was upward at 1 mph. Stack I was found closed. When the stack was opened, the flow was upward at 2 to 3 mph.

The floor of the upwind manifold in hangar 10 was covered by as much as 2 inches of snow on the southern end. The amount diminished gradually to a trace at the north end. No snow infiltration was present in the downwind manifold. Air velocities were measured at the downwind end of the building only. Ducts 1 through 49 registered between 2 and 3 mph, ducts 50 through 55 registered slightly more than 1 mph, and duct 56 registered 1/2 mph. Ducts 57 through 63 were blocked with ice. Exhaust stack I is above the blocked ducts and air was flowing <u>down</u> stack I at about 1/2 mph. At the same time, air was traveling upward out of exhaust stacks A through E at 3 to 4 mph, out of stacks F and G at 2 to 3 mph and out of stack H at 1 to 2 mph.

SECTION III

ANALYSIS OF DATA

1. SOILS

Subsurface temperature data are of limited value unless the nature and extent of the frozen ground is known.

In 1953 numerous holes were drilled through the floor of hangar 10 and into the soil below for installation of thermocouples. The soil foring logs were reviewed and a map produced showing the distance from the hangar floor to the native soil (figure 9). Boring logs indicate that the upper 6 to 24 inches of native soil generally contains little ice and probably would not produce noticeable floor settlement upon thawing. Nevertheless, the thaw danger line has been assumed as the upper boundary of the native soil.

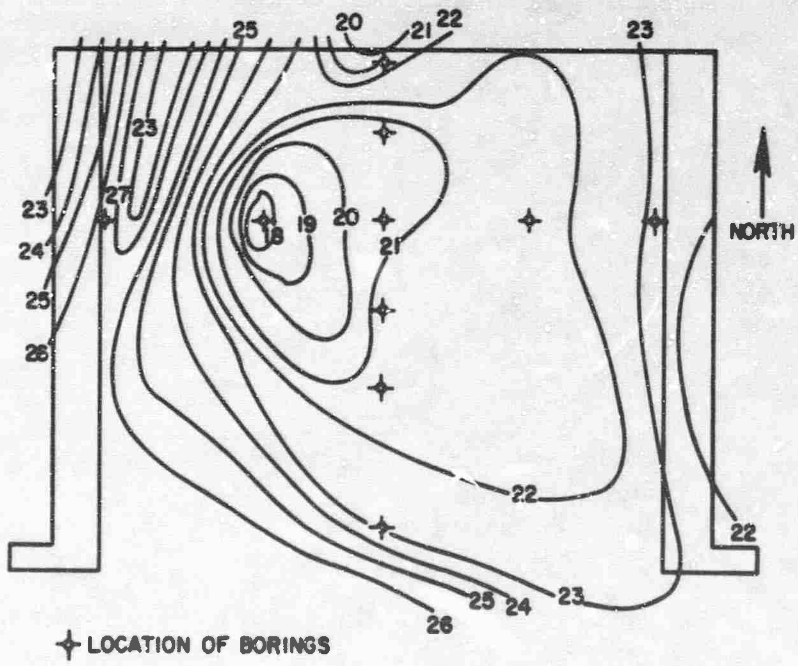


Figure 9. Distance in Feet from Finished Floor to Native Soil below Hangar 10 as Found from Soil Borirgs in 1953

During 1965, Metcalf and Eddy received a USAF-funded contract to search their files for Thule soil data so that the location of the thaw danger line could also be established for hangars 1 through 9. The elevation of the native soil was established from surveys conducted in 1951 and compared to the finished floor elevation of the hangars. Only two soil boring logs were available in the vicinity of hangars 3 through 6 and the thaw danger line could not be adequately defined in that area by the authors. The depth to the thaw danger line for hangars 1, 2, and 7 through 10 as determined by the authors from the 1951 surveys and soil boring data are shown in table II. Comparison figures based on the 1953 borings in hangar 10 are also noted in table II. A 5- to 9-foot incompatibility exists and it is felt that all the 1951 boring data presented in table II is of questionable value.

Table II

DEPTH TO NATIVE SOIL BELOW THE FINISHED FLOOR
IN HANGARS 1, 2, AND 7 THROUGH 10

Hangar	At thermocouple assembly	Depth (ft)
1	1	12
	2	10
	3	10
	4	13
	5	12
2	6	5
	7	5
7	11	8
	12	9
	13	10
8	14	13
	15	11
	16	11
9	17	15.5
	18	16.5
	19	17.5
10	26	14*
	30	13*

*The 1953 borings in hangar 10 indicate that the depth to native soil at thermocouple assembly 26 is 23 feet and at thermocouple assembly 30 it is 19 feet.

2. SUBSURFACE TEMPERATURES

Temperature profiles as measured on 9 January for the five thermocouple assemblies in hangar 1 are shown in figure 10. They indicate that the 0°C (32°F) isotherm has penetrated to a depth exceeding 14 feet below the area of maximum floor settlement as shown in figure 11. It appears that localized deep thaw penetration has caused the settlement. The information in table II suggests that several feet of native soil have been thawed. It is important to note that the maximum depth of thaw closely coincides with the location of the well from which ground water has been pumped from under the hangar.

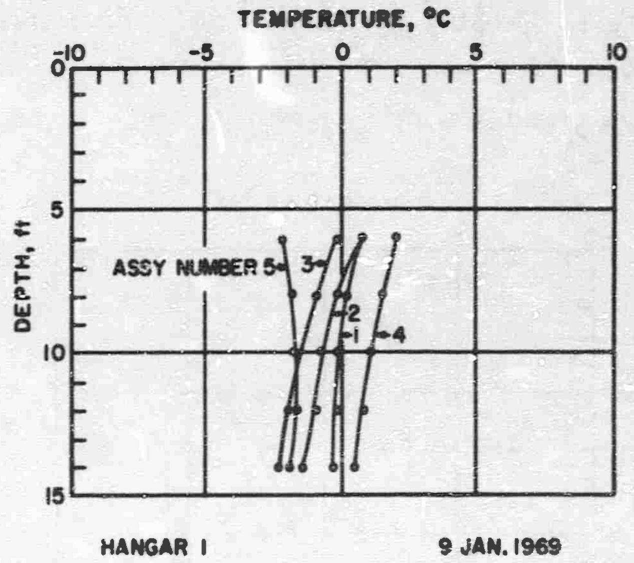


Figure 10. Measured Temperature Profiles, Hangar 1

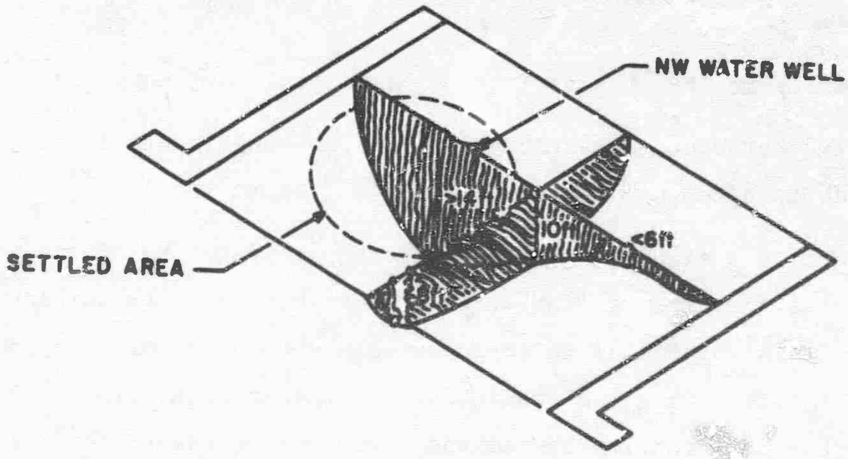


Figure 11. Location of 0°C Isotherm below Hangar 1, January 1969

The two thermocouple assemblies in hangar 2 indicate that on 9 January along the north-south centerline at distances of 18 and 45 feet from the south well, the depth of thaw was about twice that observed at similar positions in hangar 1 (figure 12). Hangar 2 has suffered severe floor settlement and the increased depth of thaw there is further evidence that the distress is the result of thawing frost-susceptible native soil. The 3-1/2-foot deep depression in hangar 2 is not centered in the western half of the hangar but is more nearly on the centerline. This is strong evidence that pumping has been a major cause of localized thaw deepening since pumping in that hangar has been conducted from both the northwest water well and one located near the center of the hangar. Ground water pumping from under other hangars has been accomplished from the northwest water well and the center of the settlement depression for these hangars has consistently formed below that area.

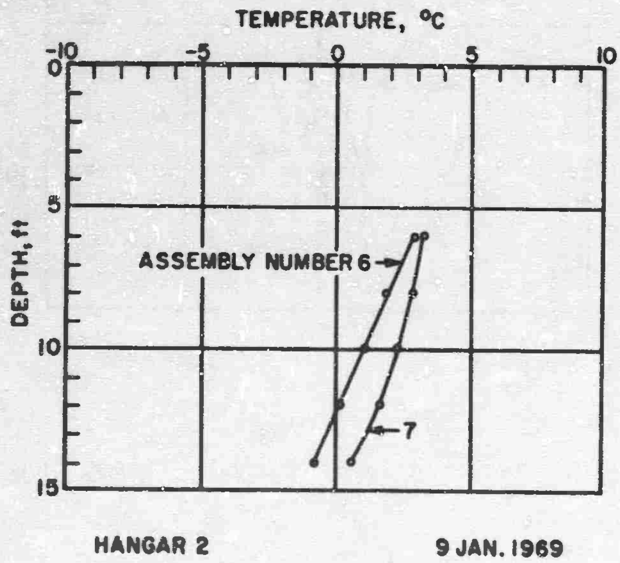


Figure 12. Measured Temperature Profiles, Hangar 2

The single thermocouple assembly (No. 7A) in hangar 3 indicates that thaw has penetrated to a depth of about 5-1/2 feet (figure 13).

The absence of a significant below-freezing temperature at the top thermocouple indicates that the cooling ducts are not having a very pronounced effect in that area (this point will be expanded upon when discussing the performance of hangars 7 through 10). The shallow depth of thaw is attributed to adequate operation of the soil-cooling system and edge cooling due to the relatively narrow width of this hangar. Since the downwind end of the soil-cooling ducts are the least effective because of progressive warming of the cooling air as it passes along the duct, it is felt that the depth of thaw penetration is even less than 5-1/2 feet toward the upwind (east) end of the hangar.

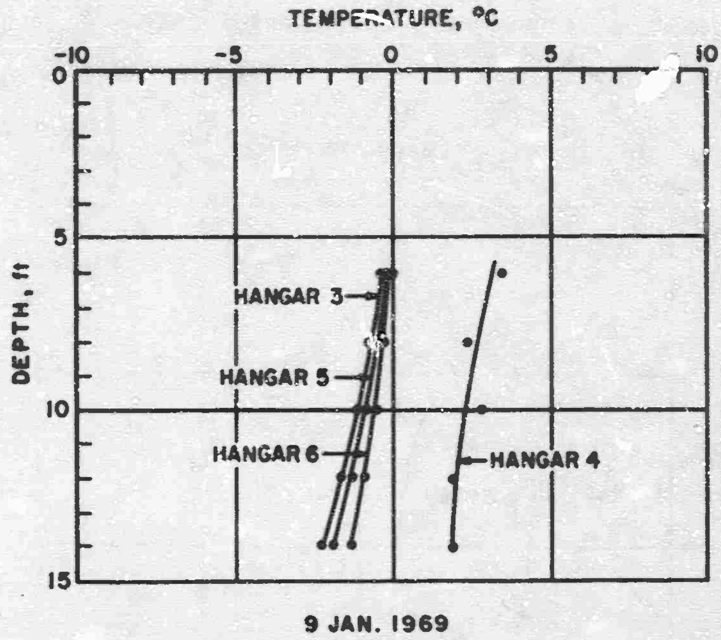


Figure 13. Measured Temperature Profiles, Hangars 3, 4, 5, and 6

The 9 January thermocouple readings in hangar 4 indicate a depth of thaw near the downwind (west) end in excess of 15 feet (figure 13). Very warm temperatures were measured and downward extrapolation of the temperature profile would indicate an exceedingly deep thaw. It is believed that the subsurface flow channel under hangar 4, detected in 1958 and described previously, still exists and is responsible for this localized deep thaw. Differential floor settlement near the doors and in the western third of the hangar was evident in 1958 (Ref. 4).

The thermocouple assembly in hangar 5 and the one in hangar 6 indicate below-freezing temperatures (figure 13). As suggested for hangar 3, the absence of significantly colder temperatures at a depth of 6 feet indicates that the soil-cooling ducts are not, at this time, freezing back the soil below. To evaluate the overall performance of the soil-cooling system in these hangars, subsurface temperatures throughout the following season would be necessary. The proximity of the hangar 6 temperature profile to the 0°C (32°F) line at a depth of 14 feet (figure 13) indicates that of the two hangars, thawing is likely to be deeper under hangar 6 during the next thawing season.

The three temperature profiles for hangar 7 are shown in figure 14. On the upwind (east) end of the hangar, the cooling effect of the ducts is quite evident. Near the center of the hangar it is somewayt less and on the downwind end very little cooling is evident. Temperatures at the downwind end are dangerously close to thawing throughout the depth of instrumentation.

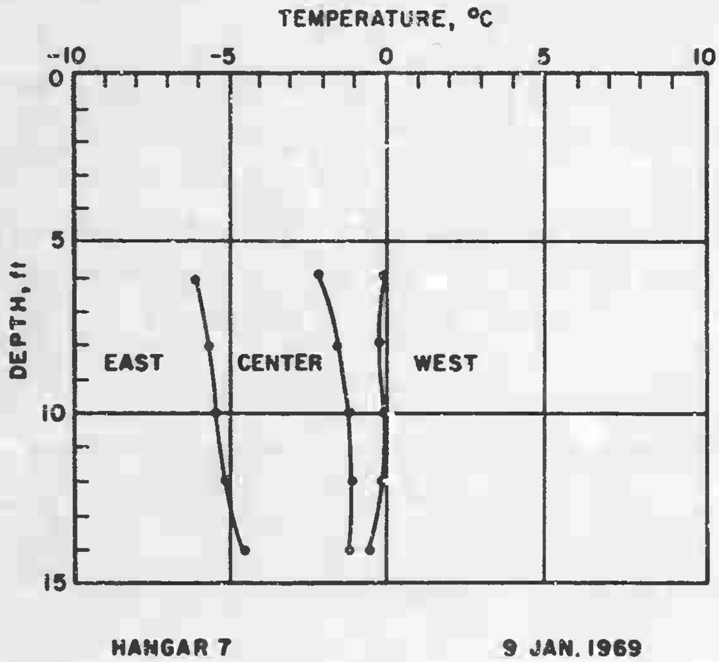


Figure 14. Measured Temperature Profiles, Hangar 7

The temperature profiles for hangar 8 (figure 15) show a similar decrease in soil cooling, progressing from east to west in the hangar. Near the west end the soil is isothermal at the freezing point and thaw probably exceeds a depth of 14 feet.

The condition is even more severe for hangar 9 where above-freezing temperatures are evident throughout the instrumented depth on the western end of the hangar (figure 16). This is probably because of partial blockage of the downwind end of nine ducts in this area.

Localized settlements of about 1 foot are present in hangars 7, 8, and 9. In each hangar the depression dish is roughly centered around the northwest water well.

A decreasing effectiveness of the downwind end of the soil-cooling ducts is also evident in hangar 10 (figure 17). Air was flowing through the instrumented duct when the measurements in figure 17 were obtained. Thaw has progressed to

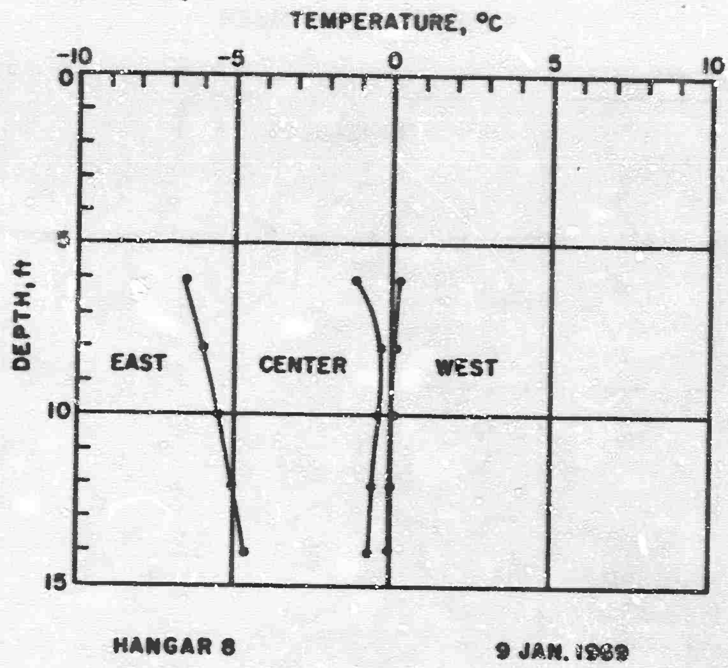


Figure 15. Measured Temperature Profiles, Hangar 8

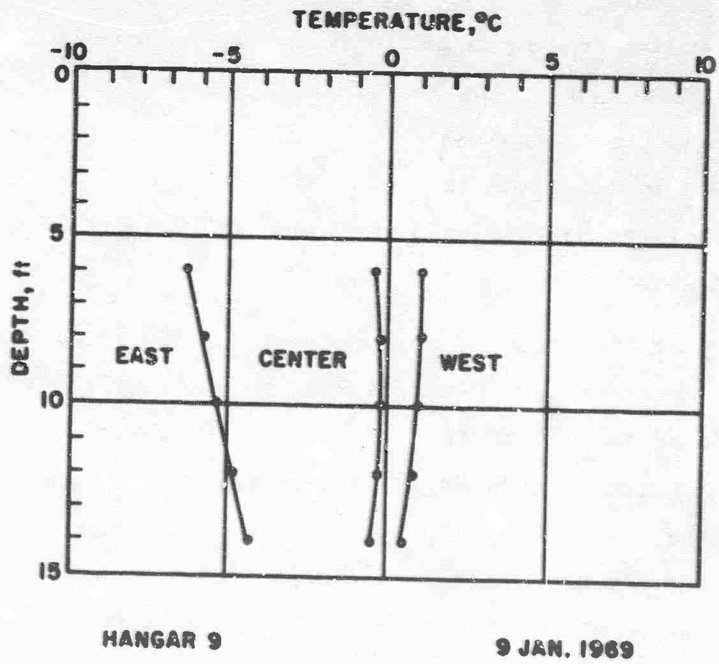


Figure 16. Measured Temperature Profiles, Hangar 9

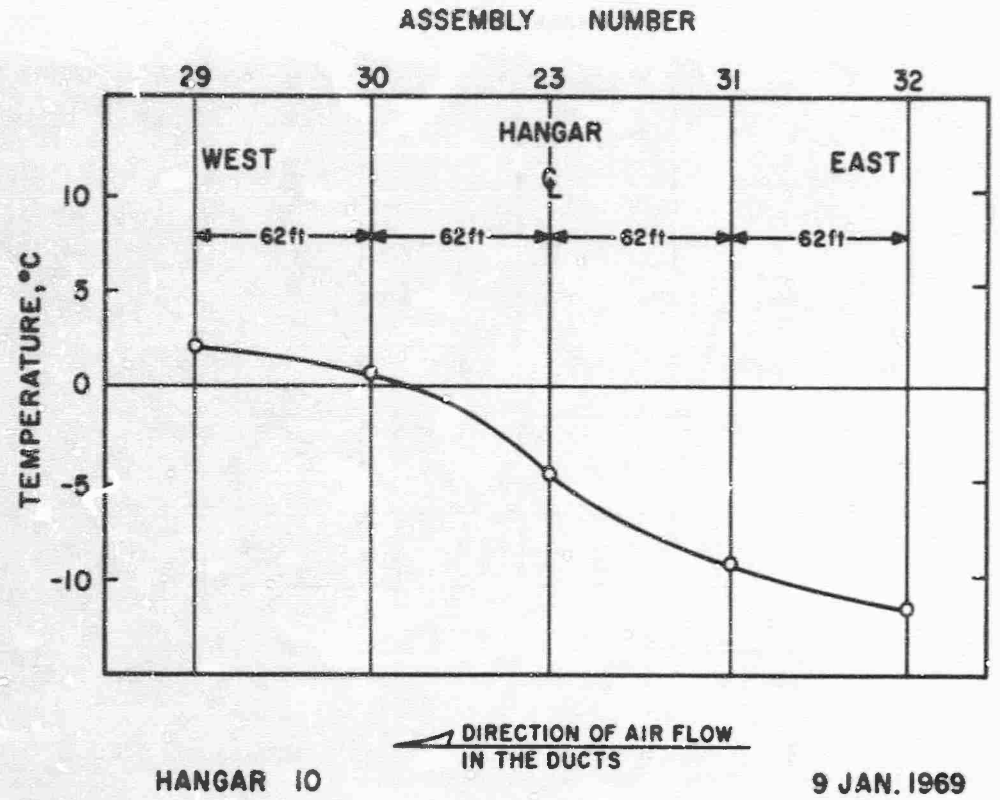


Figure 17. Measured Duct Temperatures along the East-West Line of Instrumentation, Hangar 10

a depth of 23 feet near the northwest water well as shown in figure 18. It is felt that concentration of ground water flow by pumping is responsible for localized deep thaw penetration near the well. The soil borings obtained in that hangar permit locating the thaw line and the zone of thawed native soil. The center of the large depression dish is about 2.3 feet below the hangar floor at the southeast corner.

A review of past thermocouple measurements on file at USA TSC indicates that the maximum depth of thaw generally occurs between October and December and the coldest temperatures 10 to 20 feet below hangar floors are present during the period March through May. In hangars 1, 2, 3, and 5 through 9 the temperature of sensors at a depth of 14 feet below the floor of the hangar have risen between 1 and 3°C since 1957. Although such warming is noticeable for all thermocouple assemblies, those located toward the downwind end of the hangar generally show more warming than those located near the upwind end. Sufficient data do not exist to determine if the rate of temperature change has been uniform through the past 10 years or is increasing or decreasing.

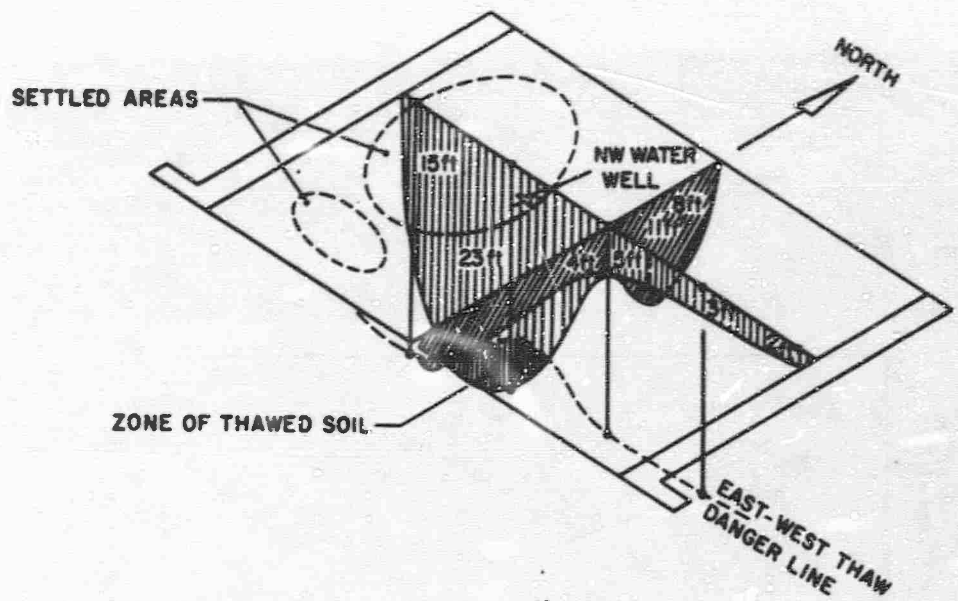


Figure 18. Measured Thaw Penetration, Hangar 10, 9 January 1969

A gradual warming is also present under hangar 4, but this effect is overshadowed by extreme fluctuations in soil temperature because of localized ground water flows under a portion of that hangar.

Warming is also present under hangar 10. Sufficient data are available to indicate that the rate of warming at depth is decreasing as shown on figure 19. This indicates that a steady state heat flow condition is being approached and the rate of thaw penetration is slowing down. This is further documented by elevation surveys conducted by the personnel of the Base Civil Engineering Division which indicates that the rate of floor settlement in hangar 10 has decreased since 1963 (figure 20).

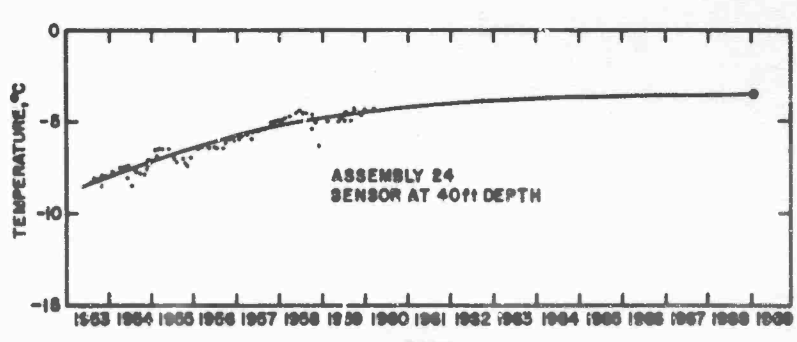


Figure 19. Progressive Warming of Soil 40 Feet below Hangar 10

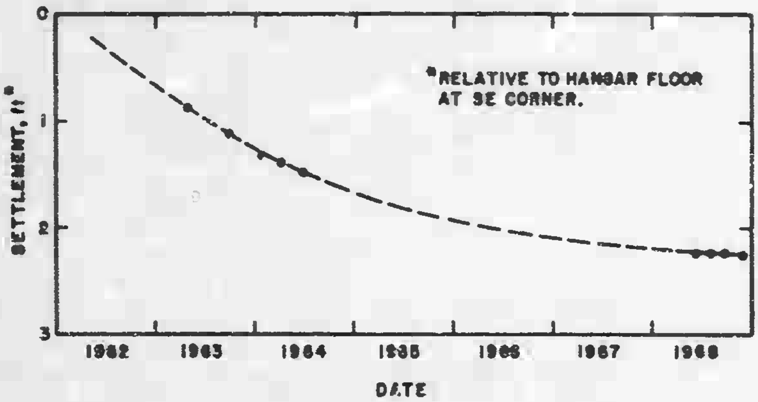


Figure 20. Floor Settlement at Center of Depression Dish, Hangar 10

SECTION IV

CONCLUSIONS AND RECOMMENDATIONS

The following conclusions and recommendations are based on analysis of data collected during the on-site inspection of the hangars in January 1969 and a comprehensive review of previous studies by USAF, the Corps of Engineers, Metcalf and Eddy, and the Cold Regions Research and Engineering Laboratories.

a. Although installed temperature sensors are in excellent condition, several new panel boards and switches are needed.

b. The internally-compensated precision potentiometer in use by the Civil Engineering Division is not an adequate readout device for measuring subsurface temperatures using the installed instrumentation.

c. The depth to native soil is well defined below hangar 10, but not below hangars 1 through 9.

d. The 1964 study by E. Eastburn (Ref. 5) indicates that the NFS fill is very tight. No evidence was uncovered to support the contention that removal of fines from the NFS fill by pumping of ground water has caused voids and subsequent settlement.

e. The thermocouples indicate deep penetration of the 32°F (0°C) isotherm below several hangars. Since warm temperatures consistently coincide with the location of maximum floor settlement, it is felt that thawing of permafrost is the major cause of these settlements.

f. Since the thermocouples indicate that the maximum depth of thaw is consistently located in the vicinity of the well from which water has been pumped, it appears that thawing caused by pumping of ground water from within the hangars has contributed to hangar floor settlement.

g. Past drainage surveys verify the benefits of lowering Lake Eddy and painting airdrome pavements white. However, the present paths of ground water flow are unknown.

h. In several hangars, duct blockages have significantly decreased the effectiveness of the soil-cooling systems.

i. Clearing blocked ducts is a difficult and expensive task which will continue to be required each fall unless major modifications are made to the soil-cooling systems.

j. The soil-cooling ducts become progressively less effective from the upwind (east) to the downwind (west) end of the hangars (see figure 17).

k. The trend toward progressive soil warming at depth below the hangars suggests that more winter cooling is needed than the soil-cooling systems can provide in their present condition.

l. The shallow depth of thaw measured near hangar walls and visual inspection of the hangars indicate that the pile-supported superstructures and door tracks have not been adversely affected by thaw penetration below the interior of the hangars at the present time.

1. SOIL BORINGS AND NEW THERMOCOUPLES

The major causes of hangar floor settlement can be defined using the subsurface soil information presently available. Therefore, it is felt that additional soil borings and subsurface temperatures are not needed for this purpose.

An isometric sketch of the soil conditions below hangar 10, based on visual examination of the side of the excavation made when installing piles, is shown in figure 21. The complicated nonhomogeneous soil system and isolated wedges of ice indicate that an extensive subsurface exploration program would be required to clearly delineate soil and ice boundaries within the native material. It is felt that the cost of a comprehensive soil investigation program would far outweigh any design refinements that might result from the additional information collected. However, a few checks of the depth to native soil would be helpful for corrective purposes and additional subsurface temperature information is desirable for more effective monitoring of the performance of hangars 1 through 9 once modifications are made.

If additional borings are desired, it is suggested that two 30-foot deep holes be placed in each hangar; one in the vicinity of maximum floor settlement and the other somewhat removed from the distressed area. Suggested locations are shown in figure 22. Because of the ground water channel under hangar 4, three borings are suggested there. None are suggested in hangar 5 because the gymnasium and bowling alleys were recently erected there. In hangar 10 much subsurface information is presently available and no additional borings are recommended.

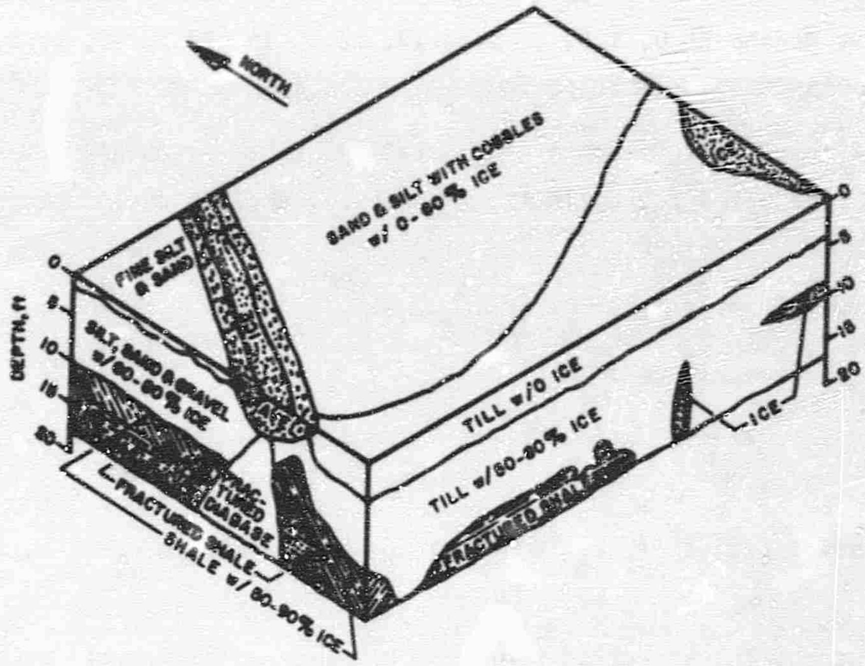


Figure 21. Isometric View of Native Soil below Hangar 10

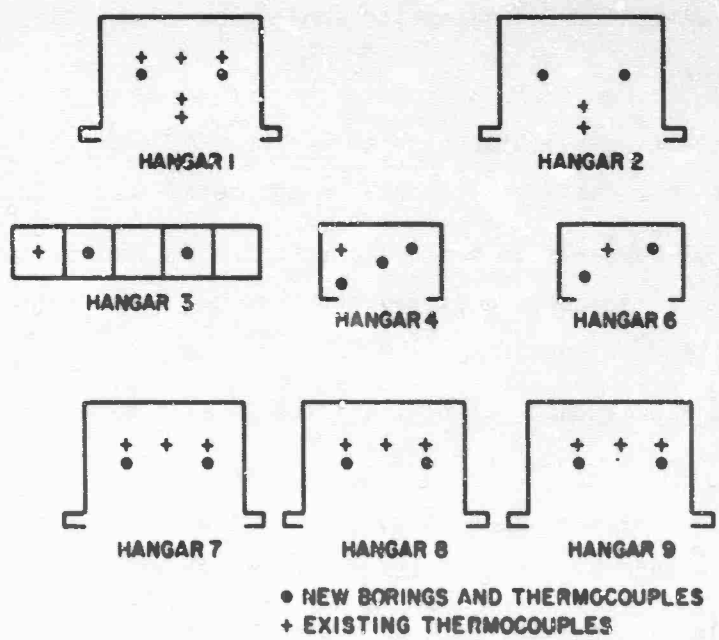


Figure 22. Suggested Location of New Borings and Thermocouples

Temperature sensors should be installed in each borehole. Twelve thermocouples located at depths of 0, 2.5, 5, 7.5, 10, 12.5, 15, 17.5, 20, 22.5, 25, and 30 feet below the floor are suggested.

If additional temperature sensors are installed, it is recommended that a formal procedure be adopted for collection, analysis, and evaluation of the data obtained.

2. EXISTING INSTRUMENTATION

The following is recommended:

a. Install new five-point panel boards for all thermocouple assemblies in hangars 1 through 9.

b. Install new rotary switches in hangar 10 for assemblies Nos. 24, 26, 30, and 31.

c. In the future, thermocouples should be measured with a precision millivolt potentiometer not internally compensated. A discussion of acceptable instruments is presented in Appendix II.

d. Purchase a vacuum flask to hold the ice bath reference junction. A steel rather than glass flask, such as that manufactured by the Stanley Company, is suggested. A device for crushing ice would also be useful.

3. DATA COLLECTION

To develop effective operation and maintenance procedures for the hangars, it is recommended that their performance be monitored in the following ways:

a. Measure all temperature sensors once a month throughout the year. Record data and plot temperature profiles on the new forms provided by USA TSC. Samples are presented in Appendix III.

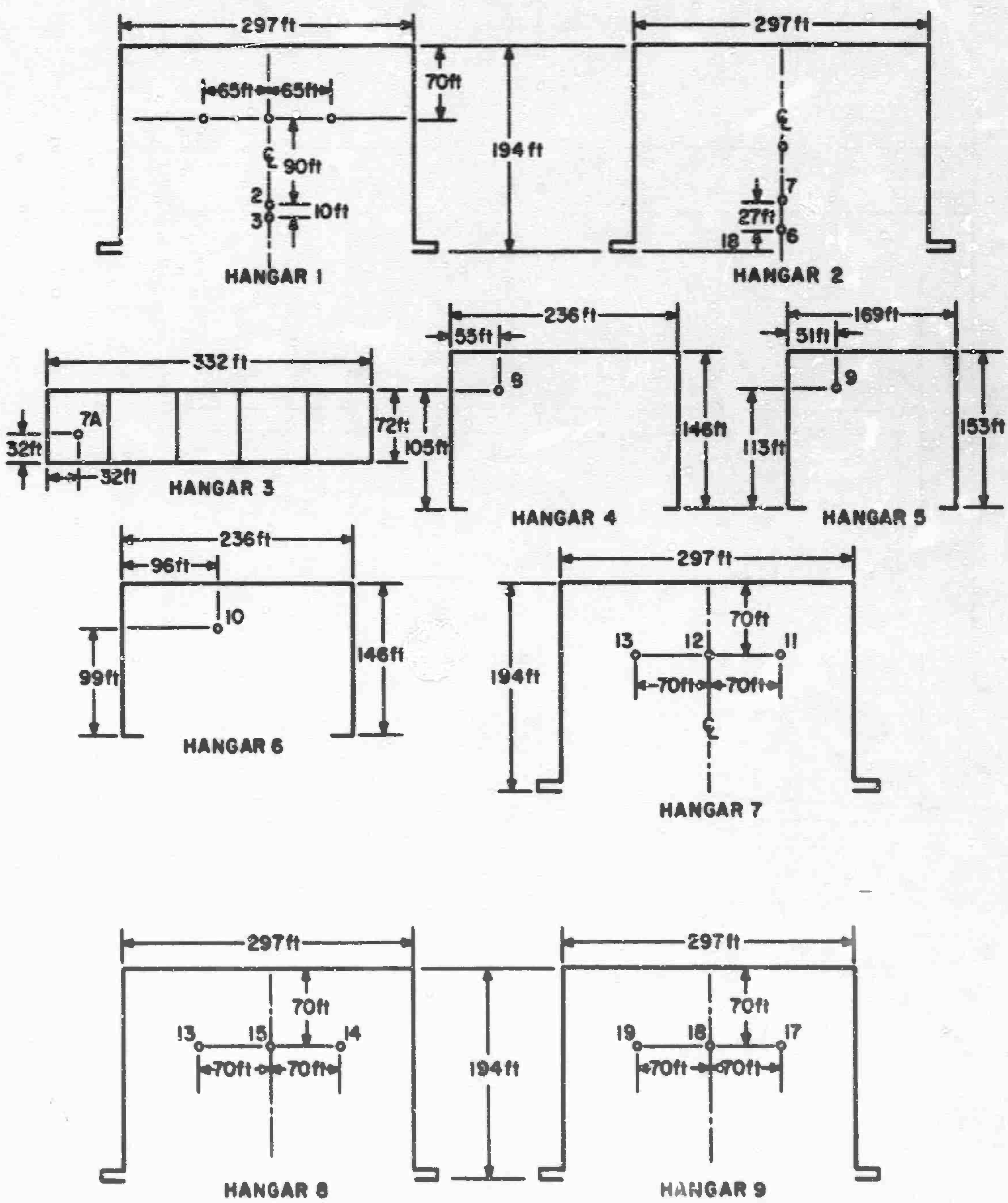
b. Produce a topographic map of the floor in each hangar once every 3 months.

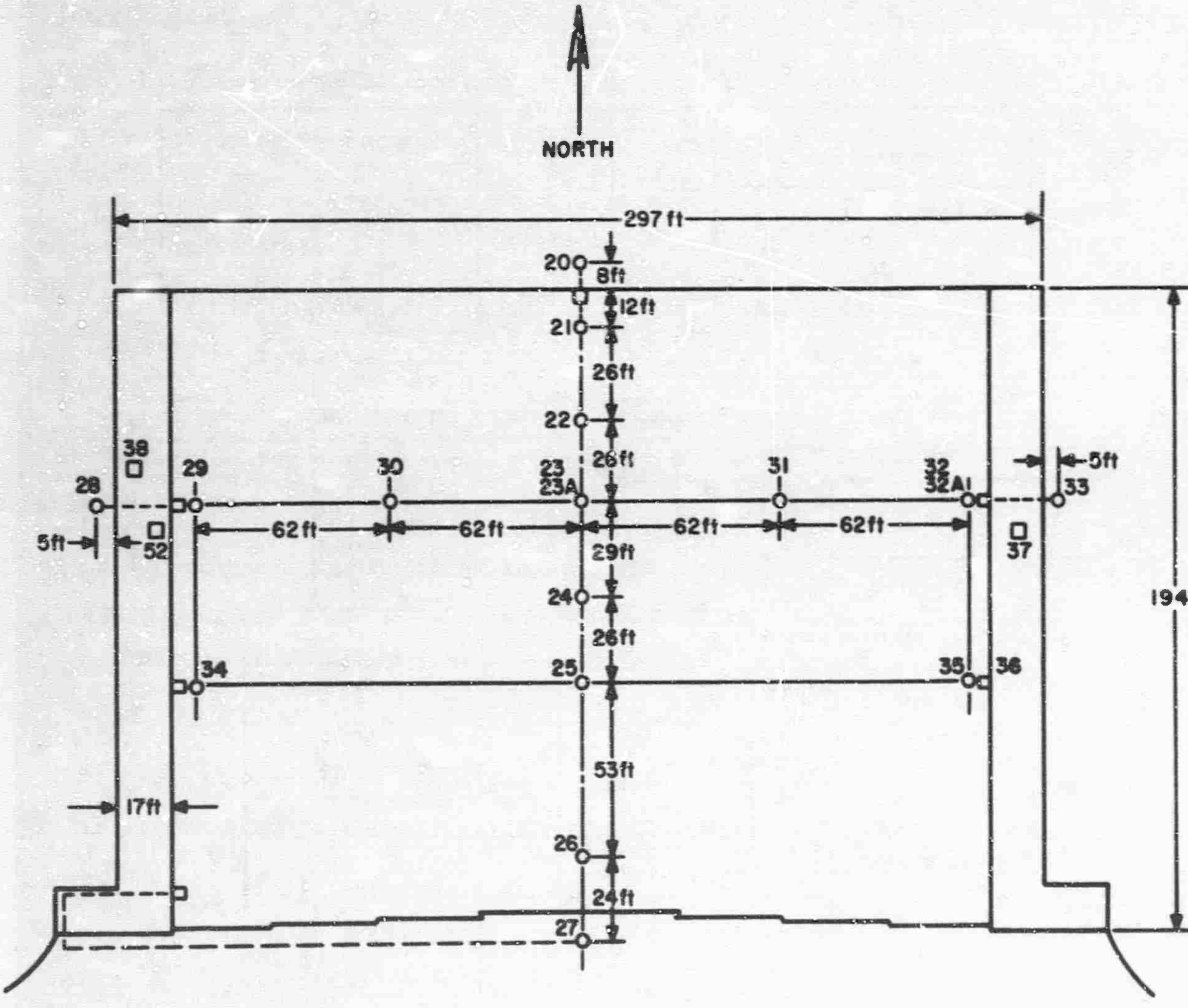
c. During the 1969 thawing season, conduct a study to determine the direction and magnitude of ground water flows within the airfield fill.

d. Throughout each thawing season, ground water elevations within the airfield should be measured at least once every 2 weeks. Weekly readings would be beneficial during the period of maximum runoff.

APPENDIX I

THERMOCOUPLE LOCATIONS





HANGAR 10

LEGEND
O LOCATION OF SENSORS
□ LOCATION OF READOUTS

APPENDIX II

ACCEPTABLE INSTRUMENTS

Subsurface temperatures at several arctic installations have been measured with potentiometers purchased from Minneapolis-Honeywell Regulator Company several years ago on special order. They were designed to be used with copper-constantan thermocouples and an ice bath reference junction. Readings were obtained directly in centigrade degrees over the rang -60 to +120°C. To our knowledge Honeywell is reluctant to make "specials" at this time and such a potentiometer would be quite expensive. Their Rubicon Model Nos. 2732 and 2733 potentiometers could be used but readings are obtained in millivolts and conversion to a temperature scale would be necessary. Also, connecting wires would have to be reversed to read sensors subjected to below freezing temperatures. Leeds and Northrup Company, Inc., Model No. 8690 potentiometer also reads in millivolts and a conversion would be required. However, that instrument is equipped to measure below freezing temperatures and connections would not have to be reversed. Since that instrument is contained in a metallic case, an outer insulated cover would be needed to maintain the batteries in a relatively warm environment.

The Thermo-Electric Company, Inc., Super Mite Model 31108 potentiometer could also be used, but again temperature conversion would be necessary. The Super Mite is small and well suited for use in the field. Thermo-Electric Company, Inc., will provide Super Mite models with special scales. Procurement of a special Super Mite model equipped to read directly in degrees Centigrade over the temperature range -45 to +30°C when copper-constantan thermocouples and an ice bath reference junction are used is suggested. Their quotation No. I 59630, dated 6 March 1969, indicates that the first "special" would cost $600. Additional potentiometers with the same scale can be purchased for $360. Delivery is stated as 8 to 10 weeks after receipt of a formal purchase order.

The location of existing observation wells is shown in the Pavement Condition Report (Ref. 3) and the Airfield Drainage Investigation (Ref. 4).

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APPENDIX III

SAMPLES FOR RECORDED DATA AND PLOT TEMPERATURE PROFILES

THULE AB THERMOCOUPLES

Measured by: ______________________ Date ______________ 19____

Readings are in........................mv ☐ ....°F ☐ ....°C ☐ (Check one)

HANGAR		1	1	1	1	1
ASSEMBLY		1	2	3	4	5
CONTACT	1					
	2					
	3					
	4					
	5					

HANGAR		2	2	3	4	5
ASSEMBLY		6	7	7A	8	9
CONTACT	1					
	2					
	3					
	4					
	5					

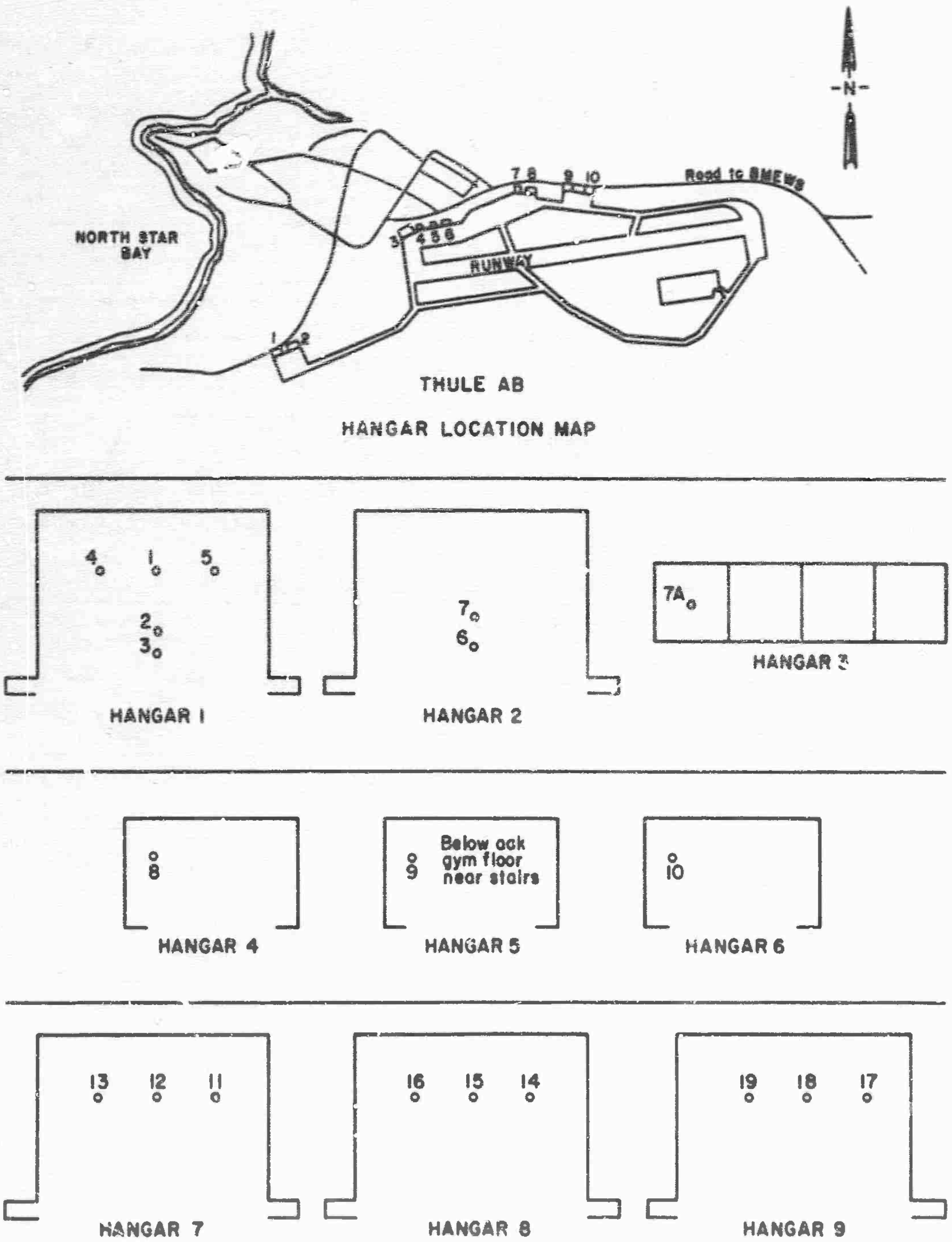
HANGAR		6	7	7	7	8
ASSEMBLY		10	11	12	13	14
CONTACT	1					
	2					
	3					
	4					
	5					

HANGAR		8	8	9	9	9
ASSEMBLY		15	16	17	18	19
CONTACT	1					
	2					
	3					
	4					
	5					

REMARKS: ____

LOCATION OF THERMOCOUPLES-HANG. S 1 thru 9

THULE AB, GREENLAND



EACH ASSEMBLY CONTAINS 5 THERMOCOUPLES SPACED 6, 8, 10, 12, and 14 feet BELOW THE HANGAR FLOOR.

THULE AB, GREENLAND

HANGAR 10 THERMOCOUPLES

Measured by ______________________________ Date ____________________ 19____

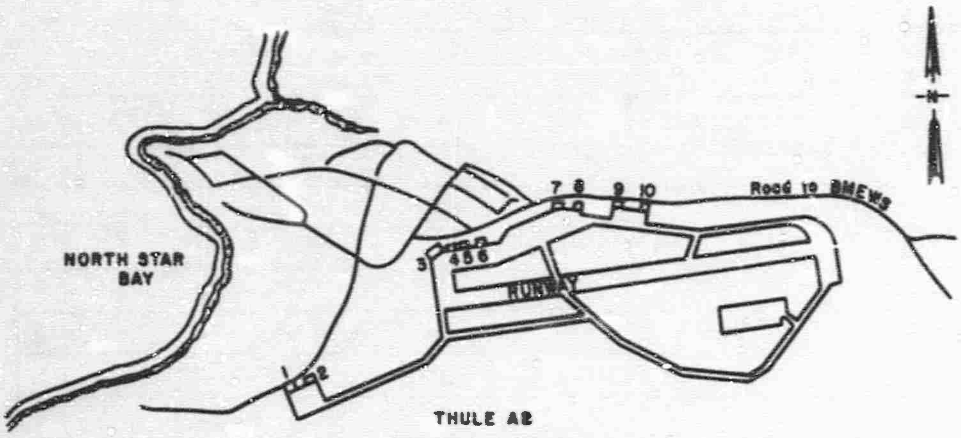
Readings are in.................... mv ☐ ..... °F ☐ ..... °C ☐ (Check one)

	20	21	22	23	23A	24	25	26	
1									1
2									2
3									3
4									4
5									5
6									6
7									7
8									8
9									9
10									10
11									11
12									12
13									13
14									14
15									15
16									16
17									17
18									18
19									19
20									20
21									21
22									22
23									23
24									24

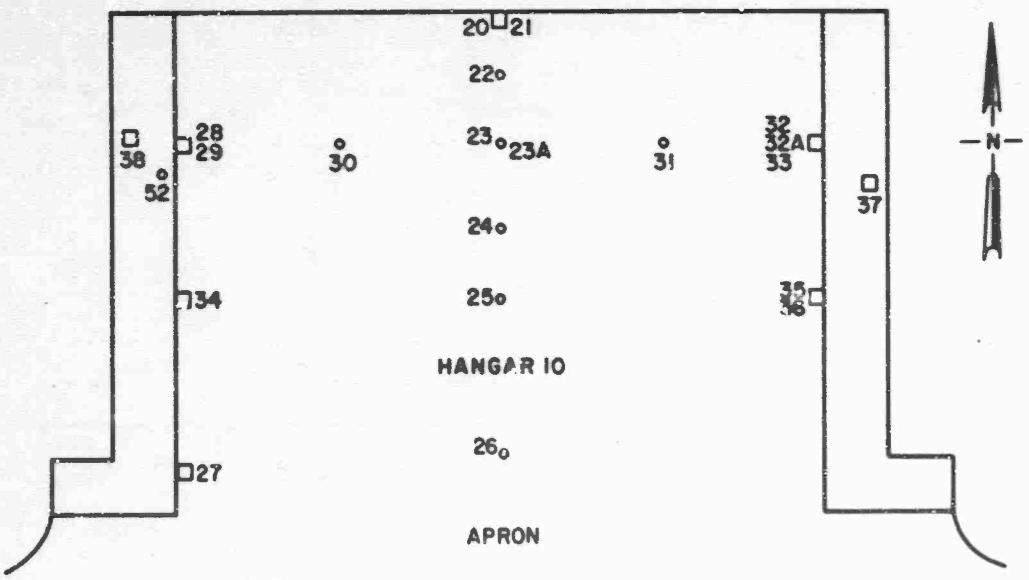
REMARKS: ____

LOCATION OF THERMOCOUPLES - HANGAR 10

THULE AB, GREENLAND



HANGAR LOCATION MAP



LEGEND

o READOUT IN FLOOR

☐ READOUT, WALL MOUNTED

LOCATION OF READOUT HARDWARE

(Sensors are not necessarily located directly below hardware)

THULE AB, GREENLAND

HANGAR 10 THERMOCOUPLES

Measured by ______________________ Date ______________ 19 ___

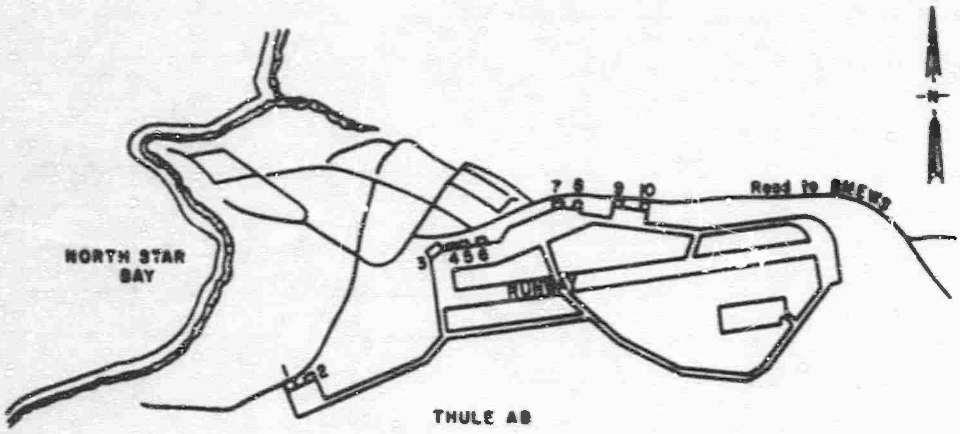
Readings are in ....mv ☐ ......°F ☐ .....°C ☐ (Check one)

	27	28	29	30	31	32	32A	33	
1									1
2									2
3									3
4									4
5									5
6									6
7									7
8									8
9									9
10									10
11									11
12									12
13									13
14									14
15									15
16									16
17									17
18									18
19									19
20									20
21									21
22									22
23									23
24									24

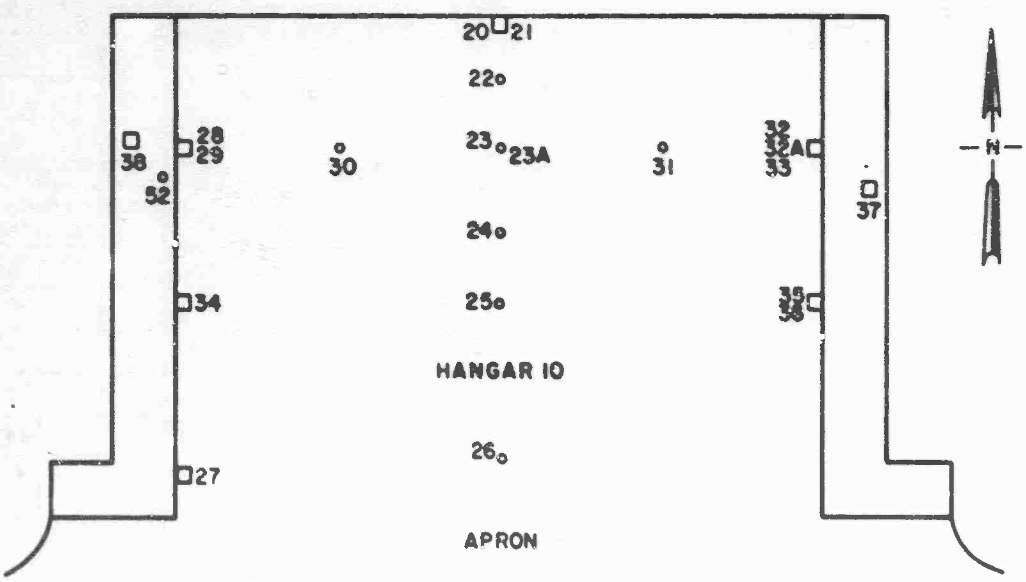
REMARKS: ______________________

LOCATION OF THERMOCOUPLES - HANGAR 10

THULE AB, GREENLAND



HANGAR LOCATION MAP



LEGEND

o READOUT IN FLOOR

☐ READOUT, WALL MOUNTED

LOCATION OF READOUT HARDWARE

(Sensors are not necessarily located directly below hardware)

THULE AB, GREENLAND
HANGAR 10 THERMOCOUPLES

Measured by ______________________ Date ______________ 19 __

Readings are in .... mv ☐ ...°F ☐ .....°C ☐ (Check one)

	34	35	36	37 Inlet*	38 Outlet*	52			
1									1
2									2
3									3
4									4
5									5
6									6
7									7
8									8
9									9
10									10
11									11
12									12
13									13
14									14
15									15
16									16
17									17
18									18
19									19
20									20
21									21
22									22
23									23
24									24

REMARKS: ____

____

____

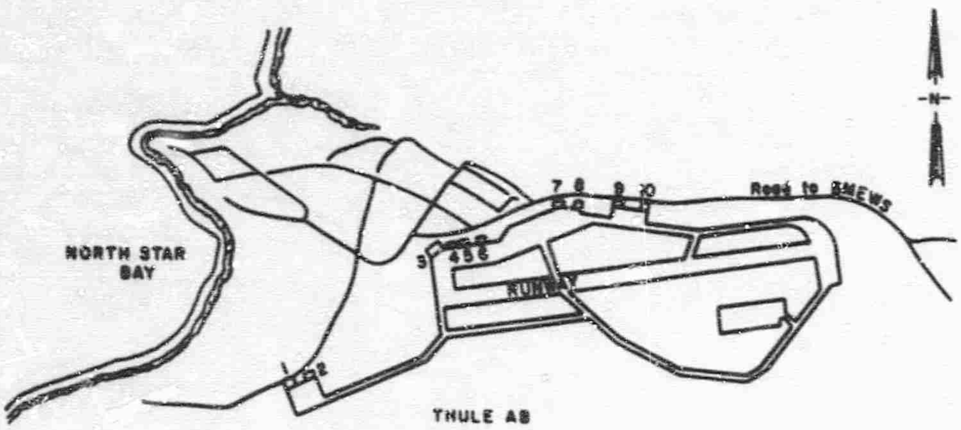
____

____

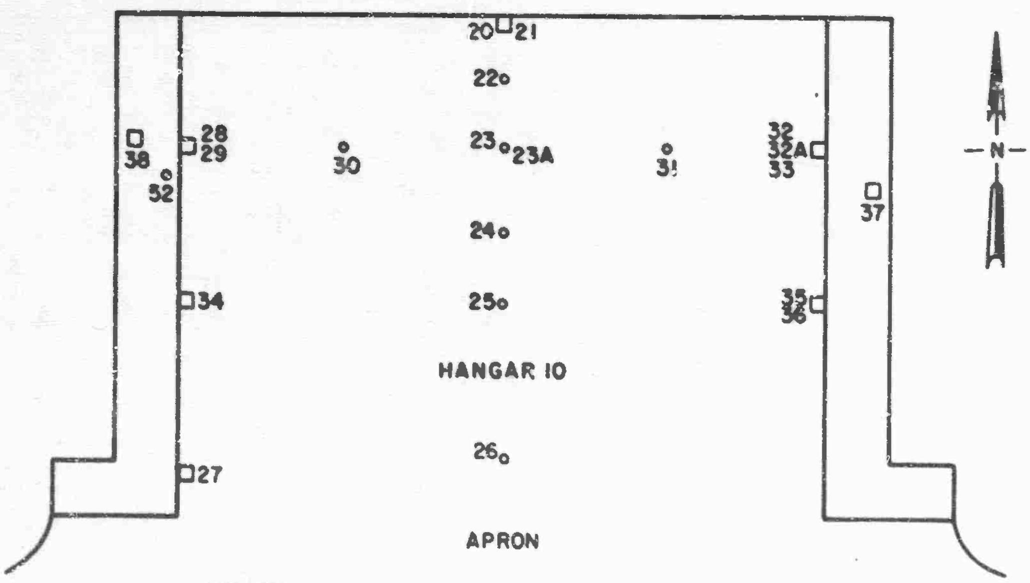
*Temps. in ducts 59, 41, 32, 22, 14, and 4

LOCATION OF THERMOCOUPLES - HANGAR 10

THULE AB, GREENLAND



HANGAR LOCATION MAP



LEGEND

○ READOUT IN FLOOR

□ READOUT, WALL MOUNTED

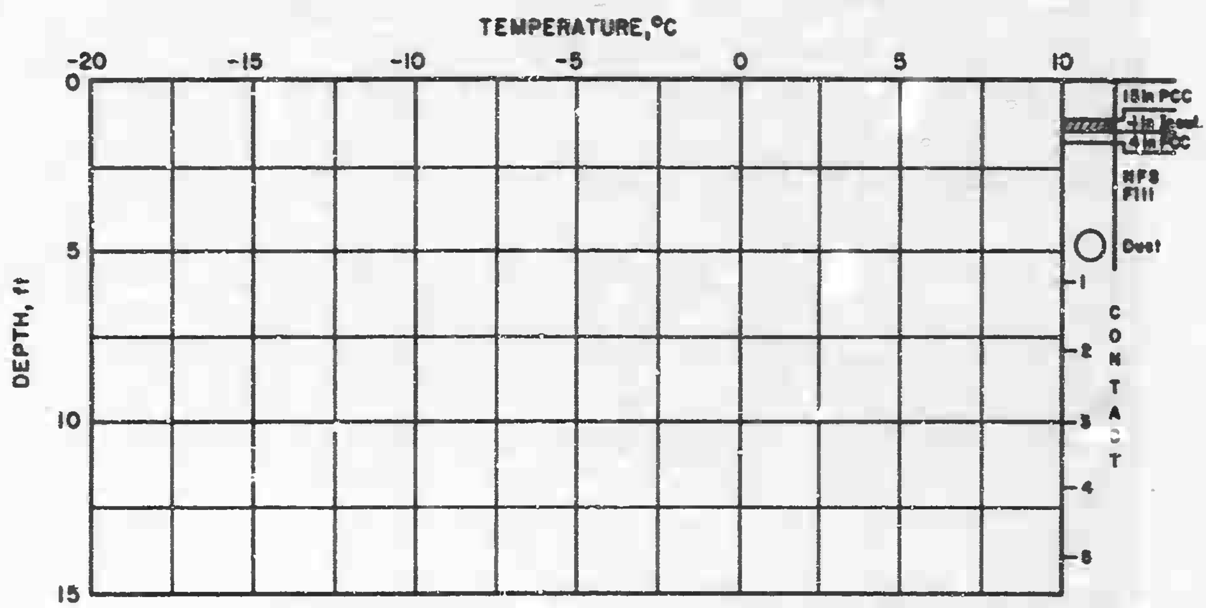
LOCATION OF READOUT HARDWARE

(Sensors are not necessarily located directly below hardware)

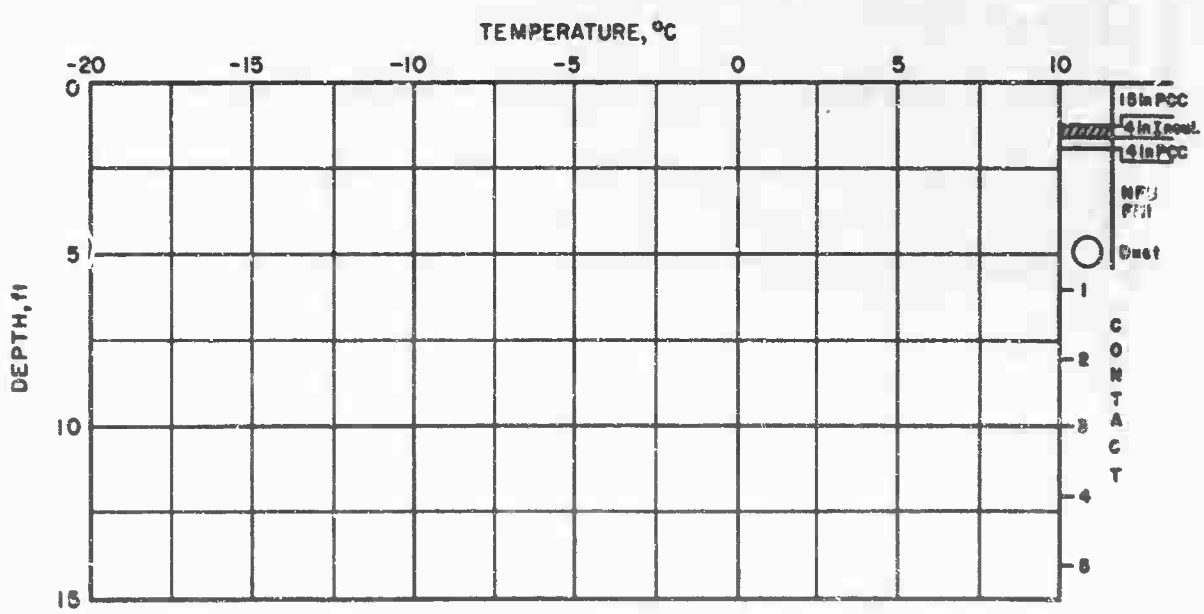
THULE AB, GREENLAND

HANGAR ————

ASSEMBLY ————



DATE ____________________ 19___



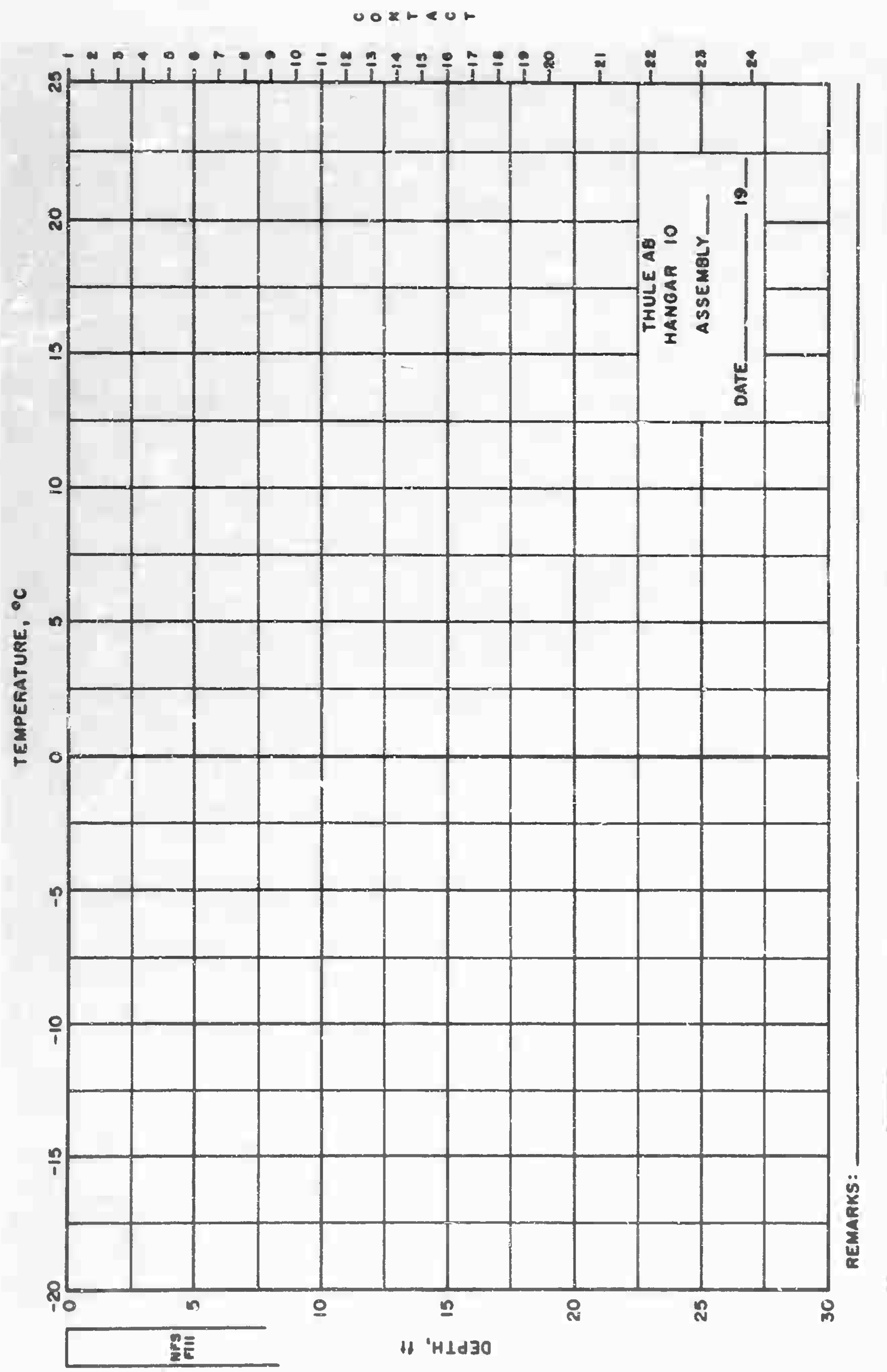
DATE ____________________ 19___

REMARKS: ____

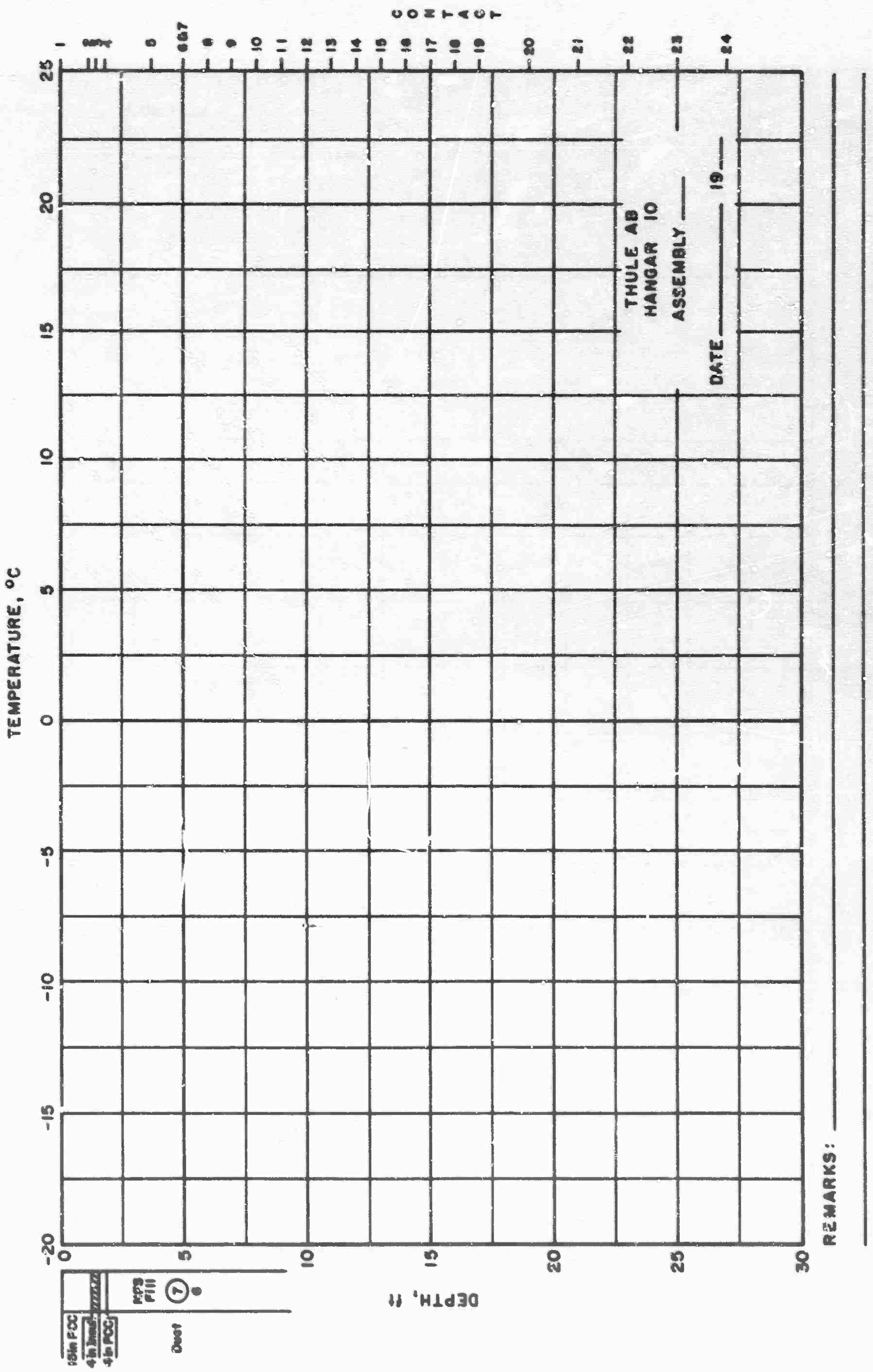
____

____

Use this form for Assemblies 1 thru 19 in Hangars 1 thru 9.



Use this form for Assemblies 20,27,28, and 33 in Hangar 10.



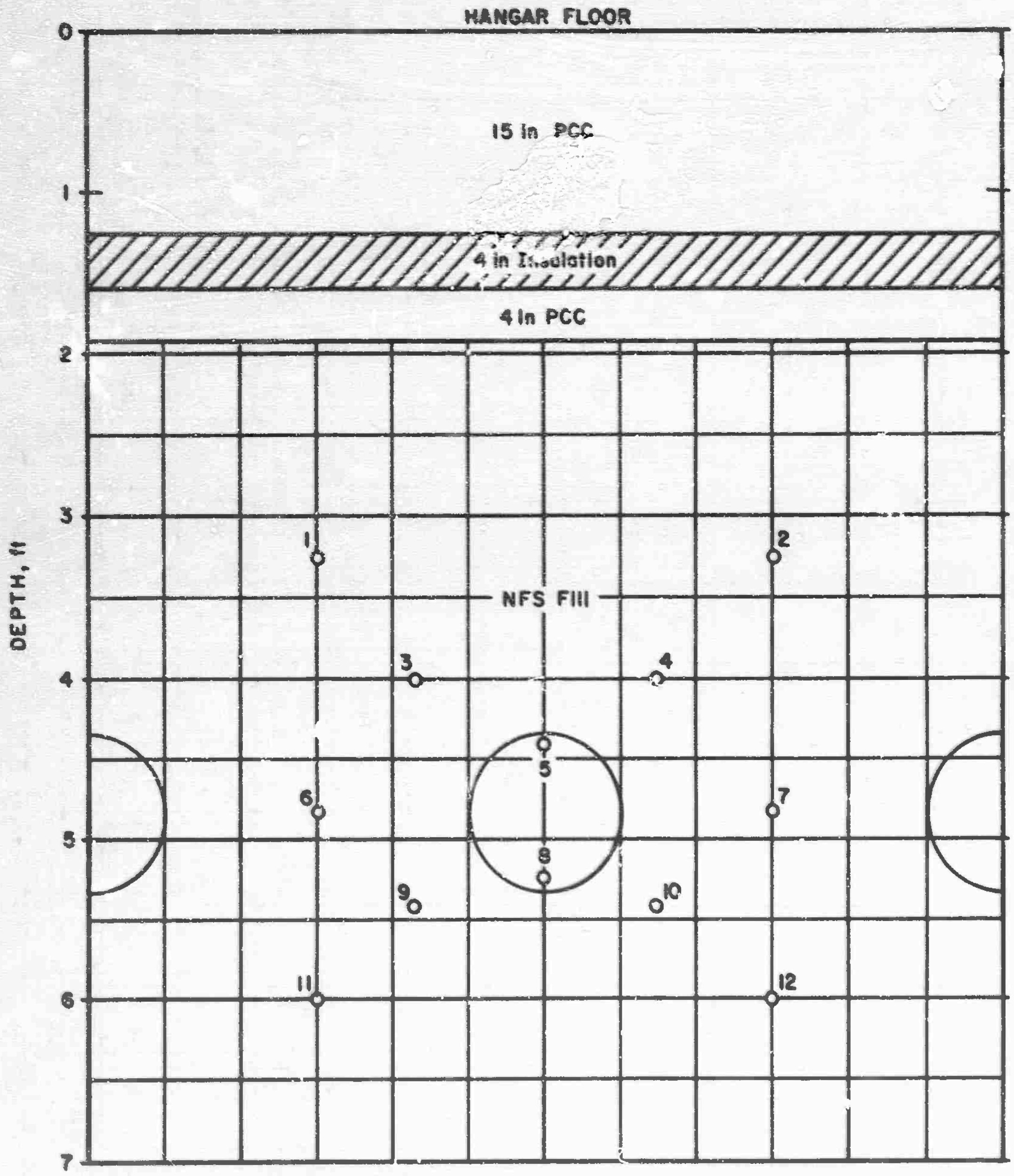
Use this form for Assemblies 21, 22, 23, 25, 26, 29, 30, 31, 32, and 34 in Hangar 10.

THULE AB, GREENLAND

HANGAR 10

ASSEMBLY ____

DATE ______________ 19__



REMARKS: ______________________________

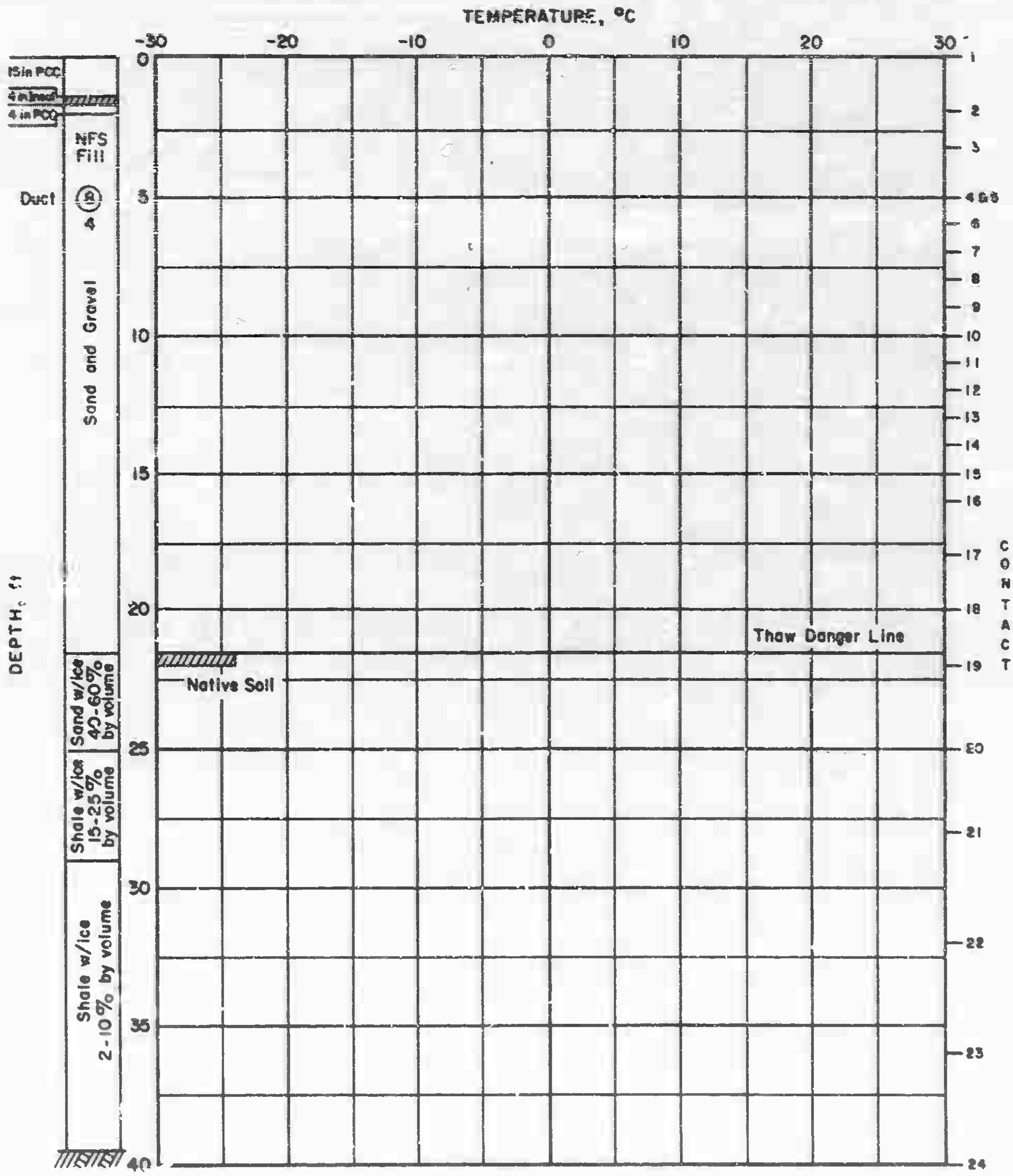
Use this form for Assemblies 23A and 32A

THULE AB

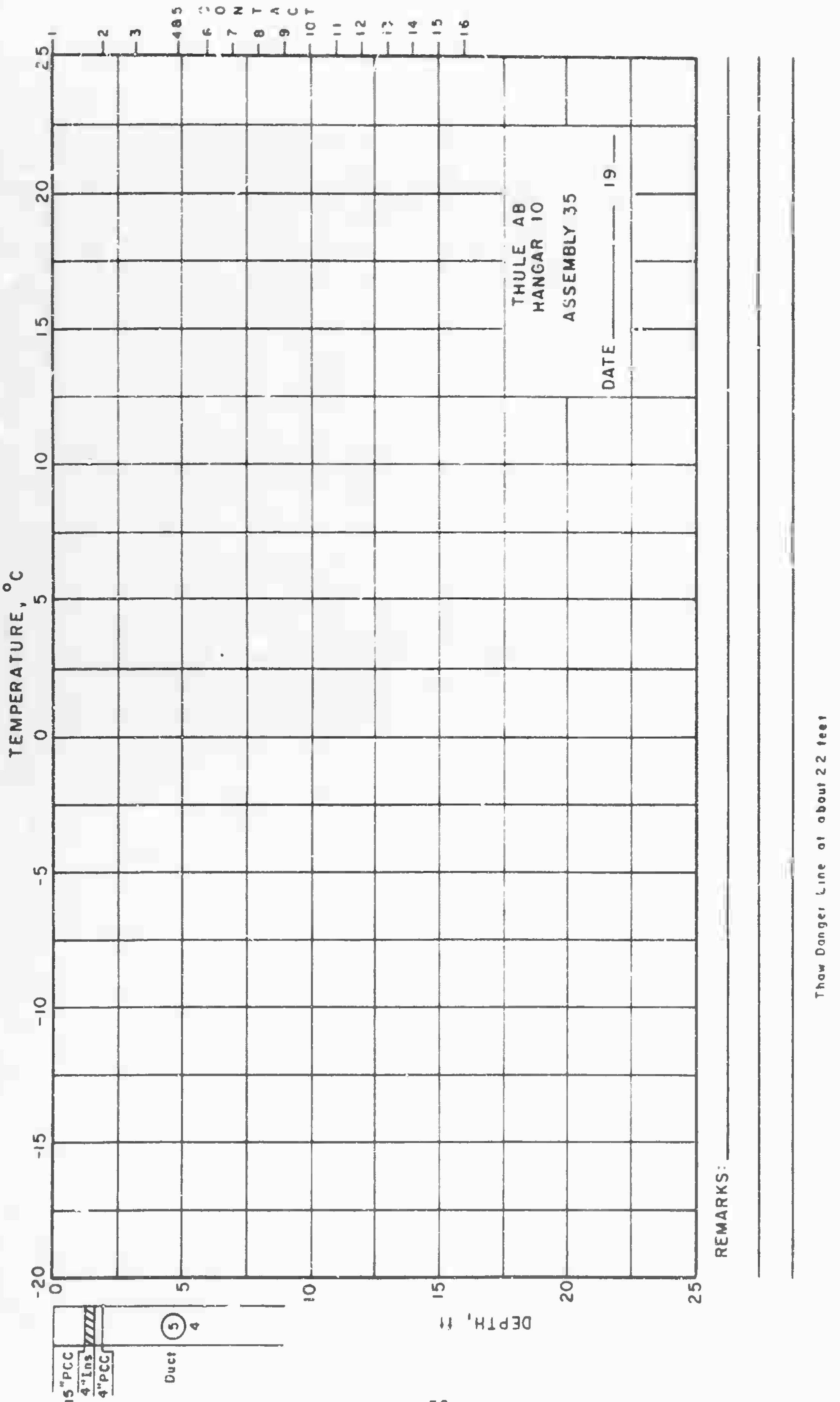
HANGAR 10

ASSEMBLY 24

DATE ______________ 19___



REMARKS: ____


TEMPERATURE, °C
DEPTH, ft
CONTACT
THULE AB
HANGAR 10
ASSEMBLY 35
DATE ______ 19__
REMARKS:
Thaw Danger Line at about 22 feet
15"PCC
4"Ins
4"PCC
Duct

REFERENCES

1. Metcalf and Eddy, Greenland Completion Report, 1951-1955, prepared for Eastern Ocean District, US Army Corps of Engineers, no date.

2. Takahashi, Yasundo, Study of Air Duct Soil Cooling Systems under a Heated Building on Permafrost (Hangar 7A-4, Thule AB, Greenland), prepared in 1956 by US Army Arctic Construction and Frost Effects Laboratory (USA CRREL Internal Report 16), 1966.

3. Metcalf and Eddy, Pavement Condition Report 1957 Supplement, Technical Report No. ENG-445, prepared for Eastern Ocean District, US Army Corps of Engineers, 1957.

4. Metcalf and Eddy, Airfield Drainage Investigation, Technical Report No. ENG-455, prepared for Eastern Ocean District, US Army Corps of Engineers, 1958.

5. Metcalf and Eddy, Airfield Drainage Investigation, Technical Report No. ENG-465, prepared for Eastern Ocean District, US Army Corps of Engineers, 1960.

6. Eastburn, Early T., Preliminary Investigation into the Sinking of the Floor in Hangar 10, Base Civil Engineering Division, Thule AB, Greenland, 1964.

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11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
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13. ABSTRACT

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An investigation has been made of hangar floor settlement problems at Thule Air Base, Greenland. Inspection of existing instrumentation and soil-cooling systems were accomplished. Results of this inspection are presented. Existing temperature sensors were found to be in excellent condition; however, readout capability was poor. Pumping of ground water has removed no fines from the fill which might have caused settlement. Major cause of settlement was found to be thawing of permafrost under floors. Pumping of ground water has caused thawing which has contributed to settlement. Duct blockages in the soil-cooling system has also allowed thawing to occur resulting in settlement. Recommendations are made to control further hangar settlement. Blocked ducts in the soil-cooling system should be cleared on an annual basis. The water table should be lowered by lowering the water level in nearby Lake Eddy. Recommendations were also made to improve instrumentation in order that effective operation and maintenance procedures for hangar foundations could be developed.

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Permafrost construction problems						
Soil-cooling systems						